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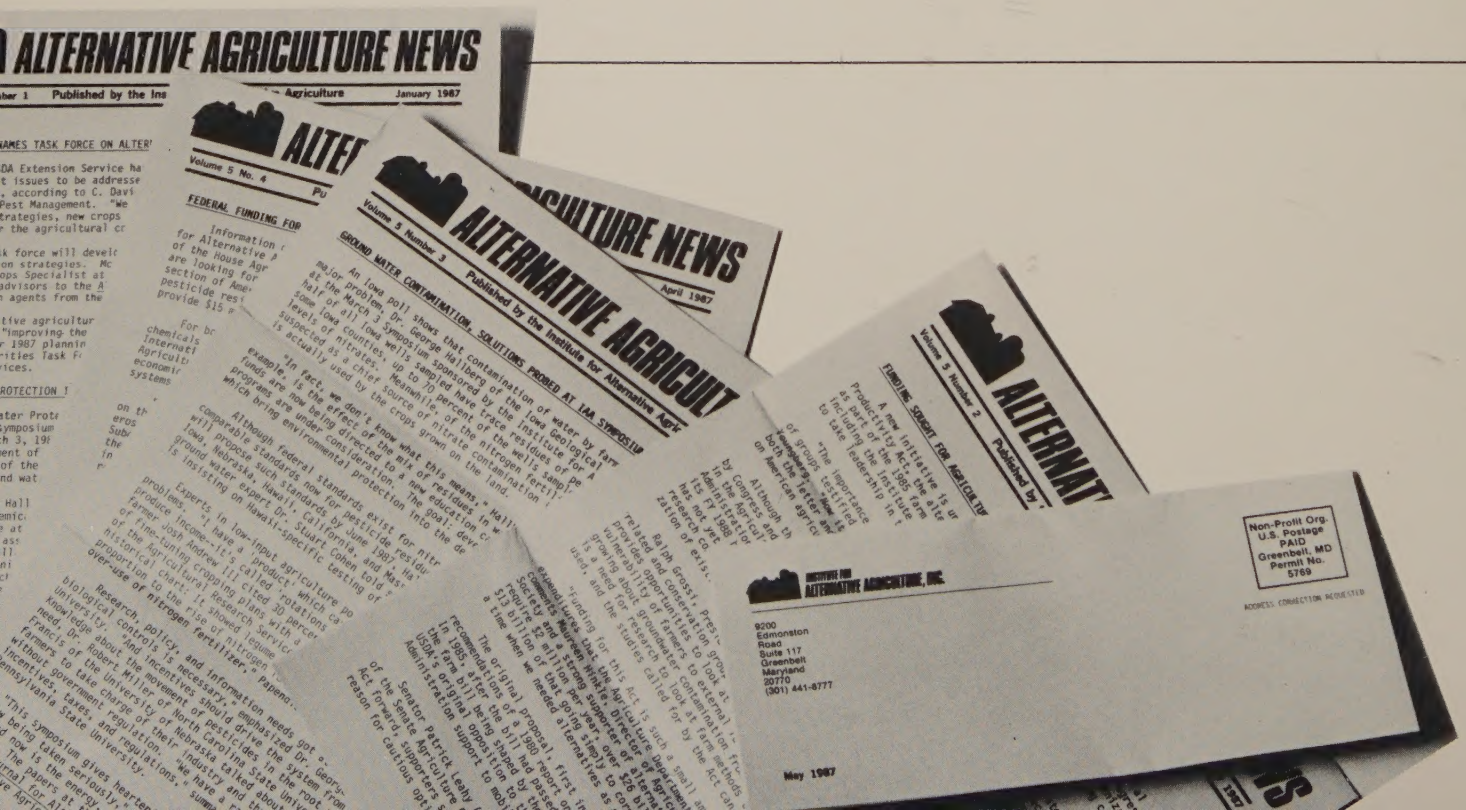

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Institute Information

The Institute for Alternative Agriculture is a nonprofit, tax-exempt research and education organization established in 1983 to encourage and facilitate the adoption of low-cost, resource-conserving and environmentally-sound farming methods. It works closely with producer groups, public research and education institutions, and government agencies in promoting a sustainable agriculture system.

Its programs include providing a national information clearinghouse, serving as a voice for sustainable agriculture in Washington, and developing and implementing research and educational outreach programs. It holds an annual scientific symposium and publishes a monthly newsletter.

The Institute is governed by a grass roots Board of Directors, which includes several commercial-scale organic farmers, and maintains a small professional staff. It is supported by memberships and donations and grants from foundations, corporations, and individuals.

Cover Photo

The cover photo shows peasant farmers in the Peruvian Andes weeding and hilling-up a field of potatoes. These farmers grow potatoes under rainfed conditions, with few or no purchased inputs. By contrast, a few kilometers away, commercial producers grow potatoes under irrigation and high levels of fertilizer application. Plant breeding programs in developing countries often use production methods that are more like those of commercial than peasant farmers. It is likely that the productivity of peasant farmers like those in this photo could be increased if they could obtain crop varieties bred specifically for their production environment. Photo by Gary N. Atlin, Department of Plant Science, Nova Scotia Agricultural College, Truro, N.S., Canada.

A perspective on the NRC Alternative Agriculture report

Alternative Agriculture is the title of a significant report published in September 1989, by the National Research Council. This book-size publication was prepared by the "Committee on the Role of Alternative Farming Methods in Modern Production Agriculture," a group assembled in 1985 by the NRC's Board on Agriculture, then chaired by Dr. William Brown of Pioneer Hi-Bred International, Inc. The committee was led by Dr. John Pesek of Iowa State University's Agronomy Department, former President of the Soil Science Society of America.

The committee included sixteen other prominent scientists representing virtually the entire range of the agricultural science disciplines. Moreover, the Board on Agriculture took care in selecting panelists who would approach this particular investigation with both an open mind and dispassionate objectivity. To the credit of all those involved in its preparation, the report reflects the interdisciplinary character of the committee and its abiding adherence to the best traditions of scientific inquiry. After four years of study, reflection, and review, the report is, in fact, a balanced assessment and portrayal of the present nature and future potential of alternative farming systems in modern production agriculture.

The balanced nature of the report can be easily illustrated. It notes, for example:

"Some farmers who have adopted alternative practices have been very successful, while others have tried and failed. Some who have successfully adopted alternatives experienced setbacks during the transition. Experience and research have led to a detailed understanding of some alternative methods. But many others are not well understood. Consequently, it is hard to predict where and how specific alternative practices might be useful."

"Alternative farming practices can be compatible with small or large farms and many different types of machinery. Differences in climate and soil types, however, affect the costs and viability of alternative systems. Alternative practices must be carefully adapted to the biological and physical conditions of the farm and region."

Finally, with regard to future patterns of adoption, the report states, "Ultimately, the farmers will be the ones to decide."

Despite the many positive findings in the report, its authors call for relatively modest funding of $40 million for research and education on alternative systems. Overall, current federal expenditures alone for agricultural research and education far exceed one billion dollars. Given the acknowledged potential of alternative systems, a recommendation of $40 million hardly seems revolutionary. On the contrary, this recommendation offers further evidence of the report's balance and restraint.

Unfortunately, the report's cautiously optimistic yet balanced conclusions and recommendations have been blurred by some early accounts and interpretations. Many press stories, particularly the headlines, for example, have inflated the report's language. Some trade accounts have distorted both the findings and implications of the report. Such reactions are unfortunate. Given agriculture's current problems and future challenges and needs, both here and abroad, it seems imperative to us that all economically viable and environmentally sound production alternatives should be examined with utmost care and objectivity. It is in this spirit that the NRC report should be read and evaluated. We are confident that objective readers will find it to be high on facts and low on rhetoric. We believe such readers will find a balanced analysis of the advantages and constraints and the needs and opportunities of alternative systems at both the micro and macro levels. Similarly, those areas where significant gaps in our knowledge base exist, and where additional research is needed, are clearly outlined. The same is true of the several related policy areas covered in the report.

In light of its relatively modest suggestions for change in the support of alternative farming systems, why has the so-called alternative agricultural community reacted so positively to the report, while major sectors of the conventional agricultural community have reacted so negatively? Contrary to many popular perceptions, the alternative agricultural community, by and large, has never advocated the immediate and total elimination of farm chemicals. To paraphrase, its major plea for many years to the agricultural establishment has been simply "Please come and look at these alternative systems. They are working well in many places and for many farmers. With additional support for research and education, and a more level policy playing field, we believe their potential can be more fully understood and realized."

In a broad sense, this is precisely what the NRC report concludes; and this is why the alternative agricultural community is generally enthusiastic about it. Simply put, the most prestigious research organization in the U.S. has examined alternative farming systems, including pure organic ones, and judged that such systems can contribute in many positive ways to the future sustainability of American agriculture. Given the history of neglect over the past 40 years or so, at least for now this is sufficient recognition and solace for both the advocates and practitioners of alternative agriculture.

The early negative reactions of some elements within the conventional agricultural community are more puzzling. Surely the concept of a level policy playing field accords well with the principles of our Jeffersonion-agrarian traditions. Surely a greater measure of agricultural balance and diversity would be in the best interest of contemporary American farmers. After all, many of them are now searching for new answers and new options to increasingly perplexing economic, agronomic, and environmental problems.

We believe that the NRC report represents a major contribution to the future of American agriculture. Like the diversity of the alternative farming systems that it cautiously endorses, its balance is its major strength. It creates a new opportunity for sensible and measured progress in an area of agricultural technology often clouded by distortion and misrepresentation. It is our hope that the larger agricultural community will seize this moment to move forward together in the creation of a truly sustainable food and fiber system. In this effort, given the uncertainties that lie ahead, we can ill afford to overlook developing the full potential of the alternatives outlined in this constructive and timely report.

—Garth Youngberg, Editor

OPINION

Permaculture, an ecological design for diversified family farms

Robert Domanigue

Permaculture is a new conceptual approach to agricultural development of the family farm. It was developed and promoted by the Australian ecologist Bill Mollison. Permaculture's inspiration comes from the use of ecology as the basis of design. It involves the concept of synergistic relationships; these relationships form the foundation on which all of the other principles rest. Synergy is a state in which the whole becomes more than the sum of its parts. The relationship of the parts to each other creates a new order of complexity.

A Permaculture-designed farm might have all of the same components as a traditional diversified family farm, but it would differ in the placement of these components in relationship to each other. For example, a traditional farm might have a pond, orchard, woodlot, pasture, windbreaks, access roads, etc. A Permaculture farm would have these same components, but they would be consciously integrated into the design of the whole farm.

In Permaculture design, everything is connected to everything else; it is important to keep this broad view in mind in order to develop synergistic relationships. From this, it follows that every function is supported by many elements, and every element should serve many functions. A function, for example, may be a fire break. The multiple elements which support this function on the farm might include fire resistant plants, an access road that cuts across a potential fire sector, and a pond. The principle is that if one element fails there will be other backup elements. The more important the function, the more important it is that there be multiple elements serving it. The elements should also serve different functions. A line of trees may serve as a wind break but also provide food for livestock and shelter for wildlife. A pond that is placed in a potential fire sector may also be used for raising fish and water plants and to irrigate a garden or provide water to livestock.

The purpose of all this is to create a diversity of useful connections that will lead to a stable and resilient system. To accomplish this, it is important to understand how two concepts

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are used in Permaculture design. The concepts are work and pollution. If an element's inputs (needs) are not met by other elements in the system, work needs to be done to make up the deficiency. If the outputs (products) of an element are not used by other elements, there is a potential for pollution. For example, we can consider a chicken as an element. A chicken needs food, water, and protection. It produces meat, eggs, feathers, manure, and heat. If the system is not designed to provide water, work must be done to provide it. If the system cannot handle all of the outputs of the chicken, such as manure, pollution results, a situation that could threaten the overall system. The ideal is to organize the outputs from certain elements to be the inputs for others. This then creates a coordinated situation in which the various elements are integrated throughout the farm and a minimum amount of work is needed to make up the deficiencies.

To accomplish this integration, some other principles of design are useful. When two different ecosystems meet, in natural areas, a third, more complex, system is formed. This is called the "edge effect." Diversity and productivity often are increased in the edge zone. This can be used to the advantage of the farmer. For example, an undulated pond could contain many more blueberry plants along its edge than a round pond. A zigzagged trellis would have much more area than a straight one.

Related to edge effect is microclimate. The climate near the ground can be quite variable. This should be taken into consideration when determining the needs of various plants. The farmer who works *with* the land, instead of against it, will make many observations and take note of the natural vegetation. With time, the farmer will learn a great deal about local climates, soil types, availability of nutrients, moisture, and other factors. All this information will be used in the continuing design process.

A farm is never "finished." Systems evolve. They change over time, and this should also be considered in the design. Pioneer species of plants that are useful to the farmer can be planted first. When the conditions are changed by these plants, other species may then be more appropriate in the design. For example, nitrogen fixing beans may be planted between young plum trees, which in turn will eventually be shaded out by walnut trees.

Permaculture also includes people in the design. One further principle is that of zoning. The farm is divided into zones that form concentric rings like those of a bull's-eye target. The central ring is zone 1. This zone, which includes the farmer's house, is the most intensive. Anything that requires a great deal of attention, such as a vegetable garden, is located there. Items that require less direct supervision are located further out. Zone 2 might have animals, like chickens, and an orchard. Zone 3 might have other animals like goats, geese, or sheep, as well as hardy trees and bushes. Zone 4 is for long-term development and includes timber for building or firewood, and pasture for cows. In zone 4, watering and feeding needs are minimal. Zone 5 would be an uncultivated natural area. The species of plants and animals and the strategies used will be different for each of the zones.

The Permaculture farm is by its nature a diversified farm. This diversification will provide the farmer with a greater re siliency in reacting to difficulties, but it will also require mor sophisticated management strategies. Permaculture farmers ex periment with more unusual crops along with the traditiona varieties. They may cultivate such unfamiliar crops as wild rice mulberries, june berries, hardy kiwi, nut trees, bamboo, wate chestnuts, or truffles. They also cater to specialty market through products such as sheep's milk, edible flowers, and low calorie low-cholesterol beef.

To bring about the development of Permaculture farms, w will need different approaches to research and extension. Eac farm site is unique. A Permaculture farm cannot be trans planted; it must be grown in its own native soil. This require a new role for farmers and researchers. Farmers must becom practitioner-researchers. They can be taught the basic principle of Permaculture design, but the specifics must be worked ou on the individual farms. As the farmer's experience grows, s will the complexity of connections in her or his farm.

The Permaculture concept does not stop at the boundarie of the farm. It also includes alternative marketing strategie for the products generated on the farm. Besides selling directl to restaurants and grocery stores, there may be direct link with consumers. One such method is called the "farm link." The farm is linked with 15 or 20 families in a nearby town o city. The families provide the farmer with an income and i return receive fresh, inexpensive vegetables, fruit, meat, an other products. They meet with the farmer to make seasona choices of products. Besides these direct farm-produced items there may be other benefits, such as holidays on the farm, cit help on the farm during busy periods, and educational possi bilities for the city families.

Permaculture points to a direction we can follow to solv our problems of soil loss and contamination of ground wate and to improve the overall health of our communities. Th Permaculture farmer thinks about the long-term sustainabilit of agriculture and is concerned with protecting and enrichin the land. The principles of Permaculture should help to ac complish this worthy goal.

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Breeding crop varieties for low-input agriculture

Gary N. Atlin and Kenneth J. Frey

Abstract. *Few plant breeding programs involve attempts to develop varieties specifically adapted to low-input cropping systems. Plant breeders generally select varieties in highly fertile, weed-free, densely seeded environments. However, alleles needed for achieving maximum yield in low-input environments often differ from those required in high-input conditions. Thus, when effective selection can be undertaken under low-input conditions, breeding programs specifically targeted at low-input environments should produce the best varieties for those environments. Experimental protocols for identifying such situations are described in this review. These involve (a) testing breeding lines under low- and high-input conditions, (b) estimating both the degree to which yields from the two types of environment are controlled by the same alleles and the relative accuracy with which superior genotypes can be identified in low- and high-input environments, and (c) predicting the direct and indirect responses to selection at each input level. On the basis of published data, it seems feasible to develop corn hybrids specifically adapted to production with lower rates of N application than are now commonly used in the United States.*

Key words: stress environments, genotype x environment interaction, corn breeding, nitrogen use, specific adaptation

Introduction

Plant breeders generally select crop varieties in nurseries that are more fertile, less weedy, and less subject to stresses such as drought than are the fields of most producers. Varieties selected under these conditions perform well in high-input environments but are not necessarily optimum for low-input farming. Low-input farmers might be better served by varieties that have been selected under more stressful conditions.

Breeding varieties for low-input cropping systems is not a novel idea. The most successful example of the use of plant breeding to reduce the need for inputs has been the selection of genotypes adapted to acid soils in the humid tropics. Acid-tolerant varieties have eliminated the need for liming on large areas that previously could not be cropped without heavy lime applications (Plucknett and Smith, 1982; Sanchez and Benitez, 1987). However, few plant breeding programs aim to produce varieties with reduced requirements for other inputs. The objectives of this report are (1) to review the literature for evidence of genes controlling specific adaption to low-fertility environments; (2) to present a protocol that can be used to determine whether separate breeding programs are needed for low- and high-input environments; and (3) to consider the need for a breeding program to produce corn hybrids for low-input production in the U.S.

Assessing the need for breeding programs for low-input systems

Before a separate breeding program can be recommended for a low-input production system, it must be demonstrated that the alleles controlling yield in the low- and high-input regimes are not identical. Yields in low- and high-input environments may be thought of as separate traits whose degree of genetic independence can be measured (Falconer, 1952). The statistic used to quantify the genetic relationship between two traits is the genetic correlation coefficient (r_G). A genetic correlation of 1.0 indicates that the two traits in question are controlled by the same alleles. If r_G is 0, the traits are independent. Negative values of r_G indicate that alleles conditioning high performance for one character are detrimental to the expression of the other. If r_G is nearly 1.0, separate breeding programs for the two types of environment are not justified. Thus, an estimate of r_G between yields in low- and high-input environments is prerequisite to a decision about the need for separate breeding programs. Methods for estimating r_G have been discussed by Robertson (1959), Yamada (1962), and Via (1984).

For comparisons involving low- and high-input environments, r_G is most effectively estimated as the product-moment correlation of genotypic values within low- and high-input environments:

$$(1) \quad r_G = \sigma_{GLH} / \sqrt{\sigma^2_{GL}\sigma^2_{GH}}$$

where σ_{GLH} is the covariance between the mean yields of lines in the low- and high-input environments (this is a genetic covariance because line means estimated in one environment have no environmental covariance with means estimated for the same lines in another environment) and σ^2_{GL} and σ^2_{GH} are the genetic variances estimated in low- and high-input environments, respectively.

Despite their importance, direct estimates of r_G between yields in low- and high-input environments are extremely rare in the literature. However, many observers have reported the occurrence of significant genotype x input level interactions in experiments designed to measure the response of cultivars to fertilization. Gerloff (1987) noted that intraspecific variation in growth under

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nutrient-deficient conditions could result from genotypic differences in nutrient uptake, movement across the root to the xylem, and distribution and remobilization in the shoot, as well as from differences in the efficiency of nutrient utilization in metabolism and growth. Vose (1983) reviewed the literature and concluded that genetic variation frequently occurs for each of these physiological processes. Instances of interaction between lines and N fertility levels have been reported for grain yield in oats (*Avena sativa* L.) (Brinkman and Rho, 1984), barley (*Hordeum vulgare* L.) (Gardener and Rathjen, 1975), and corn (*Zea mays* L.) (Muruli and Paulsen, 1981; Balko and Russell, 1980); between lines and P fertility levels in oats (Atlin and Frey, 1990), white clover (*Trifolium repens* L.) (Caradus, 1982), sorghum (*Sorghum bicolor* (L.) Moench) (Brown et al., 1977) and common bean (*Phaseolis vulgaris* L.) (Whiteaker et al., 1976); and between lines and K fertility in common bean and tomato (*Lycopersicon esculentum* L.) (Gabelman and Gerloff, 1983), to list only a few examples. These experiments have generally involved only a few genotypes and thus are unsuitable for the estimation of genetic correlations. However, the frequency with which genotype x input-level interactions occur indicates that alleles that confer specific adaptation to low-input environments may exist in many crop species.

The existence of such "low-input" alleles does not, in itself, justify separate breeding programs for low-input systems. This is because random variability in field trials in low-yield environments is often greater, relative to genotypic differences, than in those conducted under yield-maximizing conditions (Frey, 1964; Byth et al., 1969; Rumbaugh et al., 1984), although this is by no means always true (Johnson and Frey, 1967; Allen et al., 1978; Pederson and Rathjen, 1981). The high relative variability of experiments conducted in some low-input environments decreases the accuracy with which superior genotypes can be identified.

Heritability (h^2) is a statistic used to quantify the accuracy with which superior genotypes can be identified in yield trials. It is the ratio of the genetic variance (σ^2_G) to the phenotypic variance (σ^2_P), and is a measure of the extent to which yield differences among lines in a field trial are due to genetic rather than environmental causes. The effectiveness of selection increases as h^2 increases, and h^2 is often correlated with the mean yield. An example of this situation may be seen in Table 1, which summarizes information on mean yield and heritability in a population of 116 random oat lines in 36 Iowa yield trials. The trials were grouped into low, medium, and high-yield classes, and heritability estimates were obtained from each class; the heritability of yield in the high-yield experiments was about twice as great as in the low-yield trials. Occasionally, h^2 in a low-yield environment may be so low that effective selection is impossible, even though the existence of genes conferring specific adaptation to the environment is suspected. Under these conditions, the only workable breeding strategy for low-yield environments is to select in the high-yield environment (where h^2 is greater and, consequently, where selection is more likely to be effective). At least a portion of the genetic gains made in that environment are likely to be expressed under low-yield conditions. This extreme scenario serves to illustrate that two factors must be considered in deciding whether to breed separately for low- and high-input cropping systems: 1) the extent to which yields in high- and low-input environments are genetically independent (quantified as r_G) and 2) the reliability of genotype yield estimation (quantified as h^2) at each input level.

Falconer (1952) proposed that the theory of selection for correlated characters could be used to integrate estimates of h^2 for yield at each input level with information about the degree of genetic independence of yield in low- and high-input environments in deciding whether separate breeding programs for the two environments are warranted. Response to direct selection in low-input environments (R_{LL}) and correlated response in low-input environments to indirect selection in high-input environments (R_{LH}) can be predicted as:

$$R_{LL} = i\, h_L\, \sigma_{GL} \quad (2)$$

$$R_{LH} = i\, r_G\, h_H\, h_L\, \sigma_{PL} \quad (3)$$

where i is selection intensity (the proportion of lines selected to serve as parents for the next generation of the population), r_G is the genetic correlation between yields in low- and high-input environments, σ_{GL} is the genetic standard deviation in low-input environments, σ_{PL} is the phenotypic standard deviation in low-input environments, and h_L and h_H are the square roots of heritability in low- and high-input environments, respectively. Choice of the input level for the breeder's nursery that is expected to result in the greatest yield gain in low-input environments is reduced to a comparison of R_{LL} with R_{LH}.

Inspection of Equations 2 and 3 shows that selection in high-input environments will produce some yield gain in low-input environments whenever r_G is positive; this explains why contemporary corn hybrids outyield older hybrids and open-pollinated varieties under both high- and low-input conditions, even though the older hybrids and varieties were selected in low-input environments (Carlone and Russell, 1987; Castleberry et al., 1984). On the other hand, if r_G is low, little yield gain in low-input conditions will result from selection in high-input environments. An example of this situation is shown in Figure 1. This graph summarizes the results of a maize selection experiment conducted in Kenya by Allan and Darrah (1978). They conducted three cycles of recurrent selection in a maize population to improve its performance in crosses with locally adapted varieties. Yield testing to select parents for each cycle was conducted in field plots that received 110 kg N/ha. The authors then crossed the original population (C_0) and each of the three populations derived by selection

Table 1. Mean grain yield and heritability† (h^2) of yield of oat lines tested in low-, medium-, and high-productivity environments (Atlin and Frey, 1990).

Productivity level	Mean yield (kg/ha)	h^2
Low	1340	0.32
Medium	2480	0.56
High	3670	0.67

† Reference unit: line means in four trials, each with two replicates.

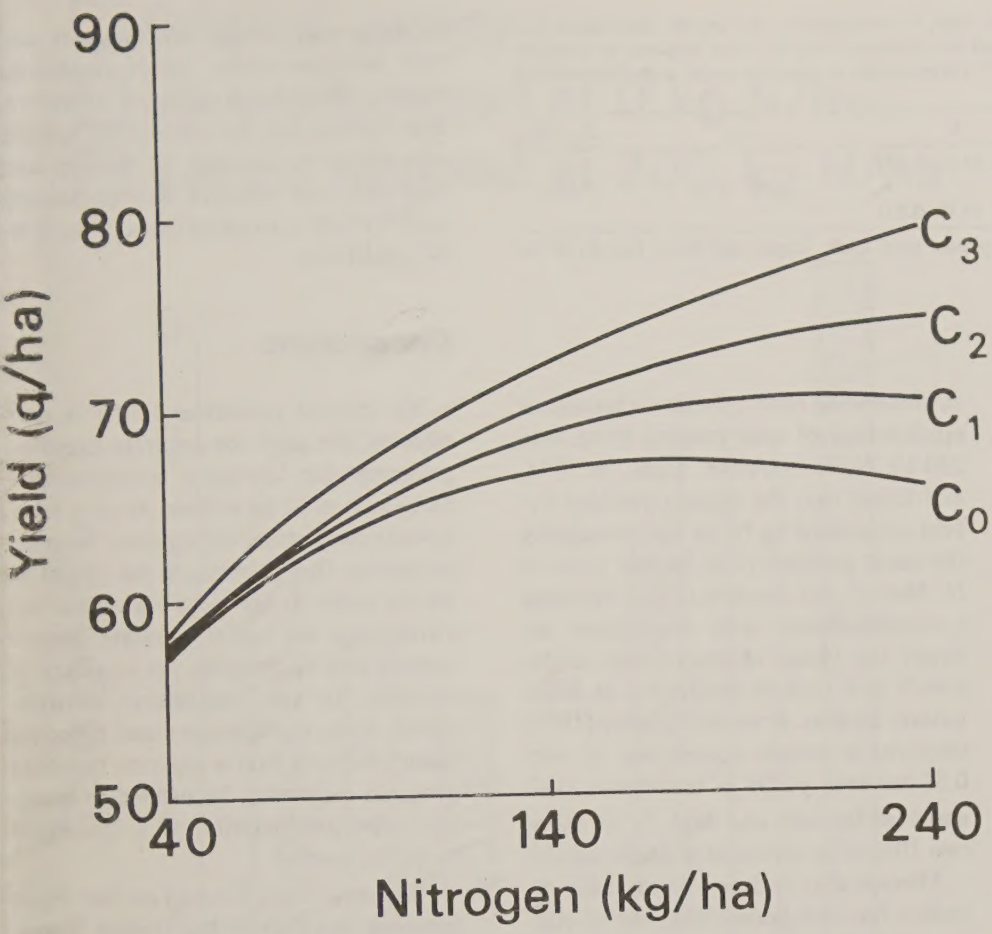

Figure 1. Nitrogen response of a corn population cross (C_0) and crosses resulting from one (C_1), two (C_2), and three (C_3) cycles of selection at 110 kg N/ha. Data combined over three locations in Kenya. (Allan and Darrah, 1978).

(C_1, C_2, and C_3, respectively) to a locally adapted hybrid and measured yields of these population crosses in plots that received 40, 140, and 240 kg N/ha at three locations. Although large yield gains were shown at the higher levels of N fertility, the selection conducted in nurseries receiving 110 kg N/ha resulted in virtually no yield increase when the hybrids were tested at the lowest N application (which is the fertility level that probably best represents that of a small Kenyan farmer's field). Under these conditions, greater gains in the low-N environment would probably have resulted from direct selection in that environment. In general, greater gains are expected from direct selection in low-input environments unless h^2 is greater in the high- than in the low-input environment and the value of r_G approaches 1.0.

We conducted several studies to illustrate how Equations 2 and 3 can be used to identify situations for which separate breeding programs in low-input environments may be warranted. In one experiment, 116 random F9-derived oat lines were yield-tested in two sets of field trials on P-deficient soils. In one set of trials, no P was applied to the field; in the other, adequate P to overcome the deficiency was applied. Mean yields and heritabilities within P levels, r_G between yields under high and low P, and the ratio of yield gains expected from direct selection in the low-P environment versus expected gains in the low-P environment from selection under high-P conditions (R_{LL}/R_{LH}), are presented in Table 2. The heritability for yield was greater in the low- than in the high-P environment (probably because the high-P trials had a greater tendency to lodge) and r_G between yields in the low- and high-P environments was low, with the result that expected yield gain in low-P environments was 2.6 times greater for direct selection than for indirect selection under high-P conditions. These results suggest that separate breeding programs to produce oat cultivars adapted to P-adequate and P-deficient environments might be warranted if P deficiency could not be easily overcome by fertilization.

The results of an experiment that used the same oat lines to determine if separate breeding programs are needed to produce oat cultivars for low- and high-N environments are shown in Table 3. In this experiment, the same genes seemed to control yield under both high- and low-N conditions because r_G did not differ from 1.0. Because the heritability of yield was greater in the high-N environment, greater yield gains for both low- and high-N conditions were predicted to result from selection in the more fertile environment.

Conclusions drawn from these experiments apply only to the oat lines used. Nonetheless, the experiments summarized in Tables 2 and 3 illustrate that before a decision is made to initiate a separate breeding program for a low-input environment both the existence of

Table 2. Heritability† (h^2) of oat yield in low-P and high-P environments, the genetic correlation (r_G) between yield in low-P and high-P environments, and the predicted ratio of direct response to selection in low-P environments (R_{LL}) versus response in low-P environments to selection under high-P conditions (R_{LH}) (Atlin and Frey, 1990).

P level	Mean yield (kg ha^{-1})	h^2	r_G	R_{LL}/R_{LH}
Low	1140	0.40 (0.22, 0.54)		
			0.52 0.24	2.63
High	2710	0.21 (−0.02, 0.40)		

† Reference unit for h^2 is mean yield in three two-replicate yield trials. Upper and lower bounds of the 90% confidence interval in brackets.

Table 3. Heritability† (h^2) of oat yield in low-N and high-N environments, the genetic correlation (r_G) between yield in low-N and high-N environments, and the predicted ratio of direct response to selection in low-N environments (R_{LL}) versus response in low-N environments to selection under high-N conditions (R_{LH}) (Atlin and Frey, 1990).

N level	Mean yield (kg ha^{-1})	h^2	r_G	R_{LL}/R_{LH}
Low	1240	0.32 (0.12, 0.48)	1.08 0.16	0.92
High	2850	0.38 (0.19, 0.53)		

† Reference unit for h^2 is mean yield in three two-replicate yield trials. Upper and lower bounds of the 90% confidence interval in brackets.

genes conferring special adaptation to, and the ability to assess the true worth of breeding lines in, that environment should be demonstrated.

Breeding low-input corn hybrids

The preliminary field research required to demonstrate the need for a breeding program specifically tailored to a low-input environment can be costly. There are, however, several cropping systems for which enough data exist to indicate that the development of varieties adapted to low-input environments is possible. One such system is grain corn production in the U.S. corn belt. Because the cost of inorganic N is a major part of the production cost of corn in this region, and because of increasing concern over pollution of ground water by nitrate from fertilizer application to cornfields, there is growing interest in reducing the level of N fertilization used in corn culture. However, farmers attempting to reduce N application must use hybrids that have been selected at high N levels since, to the knowledge of the authors, no modern hybrids specifically selected for use under low N conditions have been commercially released. There is an urgent need for the development of such hybrids.

Prerequisites for the success of a program to breed hybrids adapted to low N conditions are i) partially separate genetic control of corn yields in low-N and high-N environments, and ii) an ability to differentiate the true genetic worth of lines in low-N environments. Several authors have reported a degree of separate genetic control of corn yields under low- versus high-N conditions. Balko and Russell (1980) studied the response of 20 unselected corn hybrids to broadcast applications of urea ranging from 0 to 240 kg N/ha at Ames, Iowa, in 1978, and found that the highest yielding hybrid at 0 and 60 kg N/ha was not among the most productive at higher rates of N. Muruli and Paulsen (1981) reported a nonsignificant rank correlation between the yields of lines tested under low-N and high-N conditions at Manhattan, Kansas. Brun and Dudley (1989) observed a genetic correlation of only 0.53 between yields of testcrosses evaluated under low and high N levels at two Illinois locations in a single season.

There is also evidence that reliable selection for corn grain yield may be conducted in low-N environments. Muruli and Paulsen (1981) screened S_1 lines (derived from a broadly based exotic gene pool) in field trials at 0 and 200 kg N/ha, applied in the form of ammonium nitrate before planting. They selected the 10 highest yielding lines from each trial as parents for two new populations, which were then tested at two Kansas locations under N applications of 0 and 200 kg/ha. In the low-N environment, the population selected at 0 kg N/ha outyielded the one selected at 200 kg N/ha by about 30 percent (Figure 2). These results show that the heritability of yield under low-N conditions was sufficiently high to permit effective selection. The contention that selection for corn grain yield can be effective in low-N environments is also supported by the observations of Brun and Dudley (1989), who reported that the heritability of yield under low N and high N conditions differed only slightly on a progeny-mean basis.

These studies suggest that, in the U.S. corn belt, corn grain yields are indeed under partially separate genetic control in high- and low-N environments and that selection under low-N condition can be effective. It appears, therefore that hybrids can be selected for specifi adaptation to reduced N fertility an that the most effective way to develo such hybrids is to select them under low N conditions.

Conclusions

No general recommendation is pos sible on the need for separate breedin programs for low-input environments Decisions must be arrived at on a case by-case basis, using information from ex periments that i) measure the extent t which yields in low- and high-input en vironments are under separate genetic control and ii) compare the accuracy o selection in the contrasting environ ments. Both the literature and breedin theory indicate that a separate breedin program may often be needed to maxi mize the productivity of a low-inpu cropping system.

This review has focused on low-inpu breeding research in the United States but the need for such research is ever greater in developing countries. Devel oping countries usually have a two tiered agriculture, wherein a small pro portion of farmers produces crops with high inputs of inorganic fertilizers and pesticides, while a larger proportion pro duces without these purchased inputs Both in international crop research cen ters and in national agricultural research programs, much screening and selection of varieties is done under high-inpu conditions, in emulation of the "green revolution" strategy. It has been argued that varieties selected under such con ditions have had the opportunity to ex press their full genetic potential and thu should be the best under both high- an low-input conditions (Hammond, 1947 Mederski and Jeffers, 1973; Daday et al. 1973). This is equivalent to arguing tha selection should always be done in th environment where heritability is great est. This argument is false if separat sets of alleles control yields in high- an low-input environments. Many case probably exist where breeding program for varieties specifically adapted to low

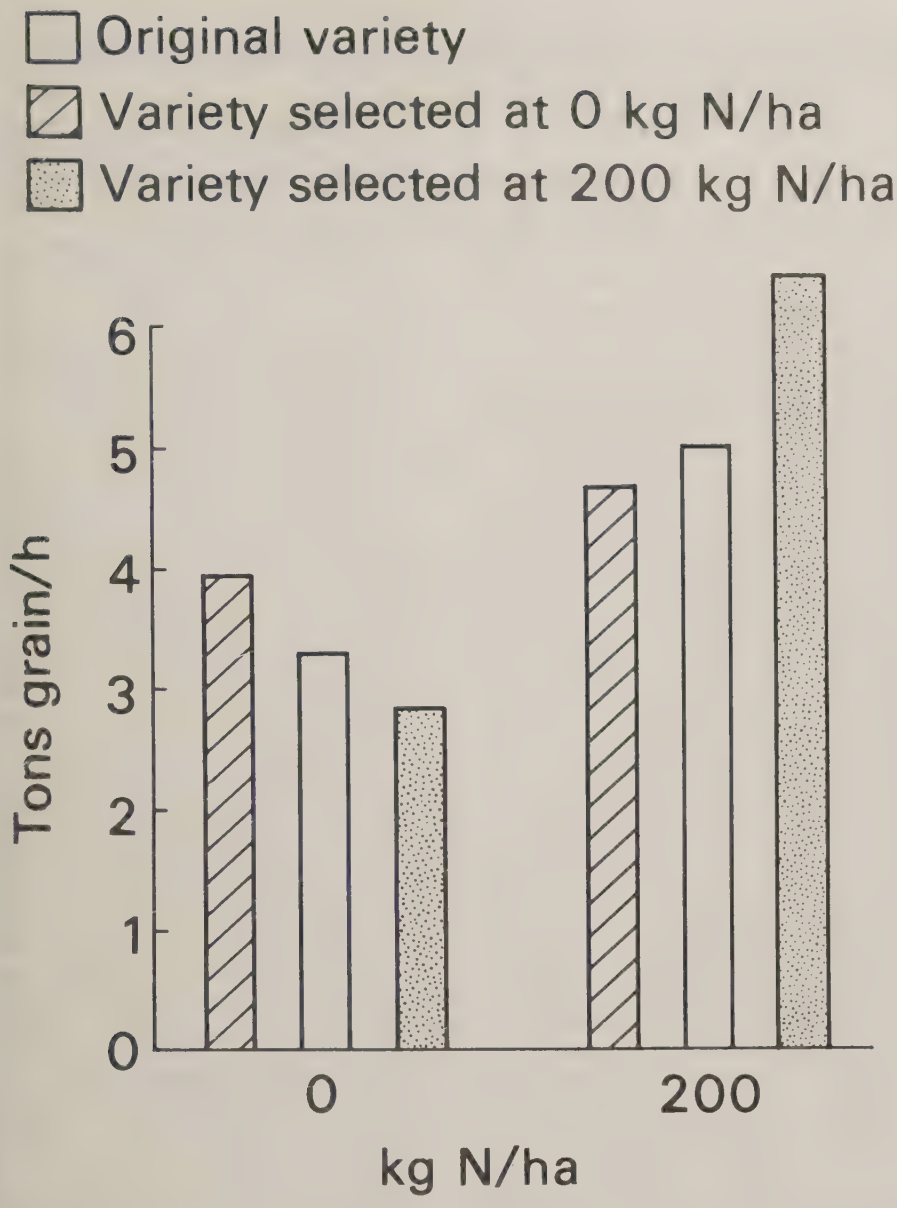

Figure 2. Grain yields, at two nitrogen levels, of an open-pollinated corn population, a population selected from it at 0 kg N/ha, and a variety selected from it at 200 kg N/ha. Data combined over two Kansas locations. (Muruli and Paulsen, 1981).

input environments are needed to maximize national production in countries where purchased inputs are accessible only to a few, and to serve the growing community of farmers in North America who are choosing to reduce their use of off-farm inputs.

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APPENDIX

Definitions

Low-input environment:	a production environment in which crop yields are reduced, relative to some obtainable maximum, due to reduced application of one or more agronomic inputs.
Line:	a progeny whose ancestry may be traced to a single plant, and the basic unit of selection in a breeder's nursery. A line may consist of a single genotype or a mixture of genotypes.
Variety:	a line or mixture of lines used by farmers.
Nursery:	a field in which a breeder observes the performance of lines and selects those that may become varieties.
Yield trial:	a field experiment in which the yields of lines and/or varieties are compared under production conditions.

Charles Stewart Mott Distinguished Professor of Sustainable Agriculture

Michigan State University College of Agriculture and Natural Resources requests applications and nominations for the Charles Stewart Mott Distinguished Professorship of Sustainable Agriculture. This endowed chair will be responsible for establishing innovative programs and catalyzing a campus-wide program of excellence in sustainable agriculture. The position has research, teaching, and extension responsibilities, with a charge to: enrich education programs with a philosophy of sustainable development; conduct research designed to impact agriculture through integration of alternative, traditional, and biotechnological management systems; develop programs to design, test, and disseminate agricultural technology; and enhance issues of sustainability and service to international agriculture programs.

MSU is searching for a scientist and leader with a distinguished record of achievement and interdisciplinary orientation. Candidates will need to possess significant research stature and organizational skills, and be broadly trained in agronomy, with the ability to interact with faculty from a diverse array of disciplines. The position will be tenured in the Department of Crop and Soil Science.

Applications for the Charles Stewart Mott Distinguished Professorship of Sustainable Agriculture will be received until January 10, 1990, or until a suitable candidate is identified. Applications, nominations, and questions should be forwarded to: Dr. George W. Bird, Chair., Charles Stewart Mott Professor of Sustainable Agric. Search Comm., Dept. of Entomology, Michigan State Univ., East Lansing, MI 48824, (517) 353-8133; FAX (517) 353-4354; Telex 650 2247573 MIC.

Farm profiles invited

For its new department on alternative agriculture profiles, the AJAA welcomes short articles describing farmers who have adopted interesting alternative practices. The articles should include five elements: a brief description of the farm; the problems that made the farmer look for an alternative approach and the reasons why the alternative seemed plausible; a summary of the basic principles behind the alternative (possibly in a sidebar if it interrupts the flow of text); a discussion of how well the alternative has worked; and a discussion of the applicability of the alternative for other farms. The length should be 1500 to 2000 words.

Submissions must be accompanied by a release, signed by the farmer, giving permission for this material to be published in the *American Journal of Alternative Agriculture*. Vol. 3, No. 4, of the AJAA has a further description of the department (page 188); or query the editor for further information. Send submissions to the Editor, AJAA, 9200 Edmonston Road, Suite 117, Greenbelt, MD 20770.

Oregon groundwater bill takes preventive approach to groundwater pollution

Oregon lawmakers have produced an $8.7 million package designed to protect the state's groundwater from toxic wastes, including agricultural waste products. The bill includes a groundwater assessment program and standards for maximum contamination levels that will trigger mandating reduction of chemicals as part of a cleanup program. $250,000 of the funding will come from increased fertilizer handling fees. Overall, the bill provides a joint approach to farm and industrial uses of toxic chemicals.

Comparison of harvest techniques for corn field demonstrations

Charles A. Shapiro, William L. Kranz, and Anne M. Parkhurst

Abstract. *On-farm field demonstrations provide a useful method of technology transfer for researchers and extension specialists, and the proponents of alternative agriculture have adopted on-farm experimentation as an important means to establish the value of sustainable methods. For on-farm research, long narrow strips harvested by machine are often employed in place of small hand-harvested plots commonly used at research facilities. The use of this approach, however, could bring the methodology into question if field variation should make determination of statistical differences difficult. Analysis of harvest data from ten irrigated and four dryland site-years for small hand-harvested corn plots and for machine-harvested long narrow strips was conducted to determine the impact of sampling method upon experimental variation. Analyses of variance indicated that six of the ten machine-harvested irrigated sites had significant yield response to applied nitrogen while only one of the ten hand-harvested sites exhibited significant nitrogen effects ($P \leq 0.10$). The difference in statistical precision was not a result of increased range in yields, but rather of more consistent yields for each treatment. An economic analysis was performed, and the results indicated that optimum nitrogen rates depended on corn and nitrogen price ratios. When 1989 corn and nitrogen prices were used, the calculated marginal profit levels between the reduced nitrogen and recommended nitrogen rate ranged from \$8.92 to -\$8.14 per ha. For the irrigated sites, when experimental variation (F-test of total sum of squares) was compared by harvest method, hand harvest had significantly greater variation than machine harvest in five experiments. Machine harvest was significantly more variable in one comparison. Coefficients of variation for machine harvest were less than for hand harvest in nine of ten irrigated experiments. For the dryland sites, differences between harvest methods were significant in one of four experiments. These data suggest that under certain conditions machine-harvested long narrow strips provide more accurate estimates of treatment differences than do small hand-harvested plots despite potential differences in soil texture, soil fertility, or available soil water.*

Key words: technology transfer, long strips, small plots, corn prices, nitrogen prices

Introduction

Field demonstrations on farmers' fields are popular as a technique for showing specific practices that have been proven through small plot research. They also have benefits as supplemental research areas (Lockeretz, 1987). International agriculture has used on-farm research/demonstrations for years, and extensive literature supports its success in technology transfer (Gilbert et al., 1980; Martinez and Arauz, 1984 referenced by Rzewnicki et al., 1988). The seed industry has popularized strip tests to show variety differences. These generally are non-replicated and used primarily as marketing tools. Their popularity, though, shows the preference of farmers for research conducted with the use of farm scale equipment (Francis et al., 1986; Thompson, 1986).

More specifically, agriculturalists interested in alternative cropping systems and practices have used on-farm research sites to conduct research and provide demonstrations to the farm community. Having research on farmers' fields allows producers to participate and to learn to conduct their own experiments. In order for the results to be useful, however, the field demonstrations need to be statistically sound and the results must be precise enough to reveal treatment differences.

Traditionally, replication is used to increase precision. Rzewnicki et al. (1988) suggest that six replications generally are necessary to determine 10 percent yield differences in field crops in Nebraska and Iowa. As the number of replications increases, the area needed to conduct an experiment increases. Havlin and Elmore (1984) suggest evaluating a maximum of 2-5 treatments to reduce field variability in order to detect treatment differences. To minimize the area required and to minimize soil variation, small plots are used in most field research. Moreover, the numbers of treatments and replications in many experiments make large plots impractical and expensive to manage.

The method in which a particular experiment is harvested is sometimes determined by practical considerations. Machine-harvesting strip tests is fast, avoids drudgery, and allows farmers to participate, but frequently machinery and labor are not available or field conditions are not suitable for machine harvest so plots are harvested by hand. An advantage of hand harvesting is that it permits collection of additional data such as total dry matter yield.

Since yield data are usually the most important data collected from field strip trials, the relationship between machine

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harvest of long plots and hand harvest from relatively smaller areas is of interest. The relative yield levels of machine harvest and hand harvest vary. Machine harvest may collect less grain than hand harvest as a result of dropped ears and losses through the combine. However, Wolkowski et al. (1988) found greater yields with machine harvest than with hand harvest as a result of losses from the stationary sheller and not the combine. What is less well known is how the harvest method affects statistical precision of an experiment and thus the ability to determine treatment differences.

The objective of this study was to determine whether differences in experimental variation resulted from harvesting corn (*Zea mays* L.) by hand or with a combine in a series of on-farm strip trials.

Materials and methods

Sites were selected across northeast Nebraska to demonstrate the value of deep soil sampling for residual nitrate nitrogen in selecting rates of nitrogen fertilizer for irrigated corn. Nitrogen at different rates was applied by various methods by each cooperator. At all sites three nitrogen rates based on soil tests were used: 56 kg/ha less than recommended rate, a recommended rate, and 56 kg/ha greater than recommended rate. Either two or three replications were used in a randomized complete block design. Details for each experimental site are given in Table 1. Research has shown that, when residual nitrogen is available to the crop, subsequent fertilizer nitrogen can be reduced by the amount of nitrogen present in the soil. The expected outcome was that the 56 kg/ha greater than recommended rate would not yield significantly greater than the recommended rate. Typically, the 56 kg/ha less than recommended rate may yield less than the other two rates.

Yields were collected by hand and by machine from each strip (Figure 1). Hand yields were collected by taking 2 rows, 6.1 m long from each strip from the most convenient side of the field, but far enough within the treatments to remove border effects of fertilizer and irrigation. Machine harvests were taken from the strips with the producer's combine and the grain weighed in a weigh wagon. All grain yields were adjusted to 15.5 percent moisture.

Statistical analysis was conducted by using PC-SAS (SAS Institute, 1987) for analysis of variance of each experiment separately and combined by year and location. Since the error variances wer not homogeneous, the combined analy sis is not presented. In Tables 2 and 4 the sum of squares term labeled "ER ROR" is the replication x treatment in teraction. The error term was used t calculate an LSD for the irrigated site (Table 2) and dryland sites (Table 4 To determine whether the variation be tween harvest methods was statistically different, a variance ratio was cor structed using the total sum of square and the appropriate degrees of freedom The PROBF function of SAS (SAS In stitute, 1985) was used to determine th probability that the two variances ar equal. (bottom of Tables 2 and 4).

The marginal profit ($/ha), shown i Table 5, was calculated by the use of th following equation:

[(Yield difference (kg/ha)/1000) Price of corn ($/metric ton)] - [Nitroge rate difference (kg/ha)* Price of nitro gen ($/kg)]

The results of these calculations sho the change in profit if grain yield wa increased 304 kg/ha by the addition o 56 kg/ha nitrogen for seven nitroge prices and six corn prices.

Hand harvests were taken before th machine harvests so yield data would b available for field tours conducted befor machine harvest took place. Hand ha

Table 1. Characteristics of sites used in irrigated nitrogen demonstration project. 1986–1988.

	Sites									
	Hoffman+			Schindler	Shane		Smith		Wrede	Bose
	Years									
Characteristics	1986	1987	1988	1987	1987	1988	1987	1988	1987	1988
Soil Type	Thurman fine sand			Valentine fine sand	Dunn loamy sand		Brazil Udic		Thurman loam fine sand	Lamo silty clay loam
	Udorthentic Haplustoll			Typic Ustipsamments	Aquic Haplustoll		Argiustoll		Udorthentic Haplustoll	Cumulic Haplaquol
Number of:										
rows/plot	12	12	12	12	8	8	12	12	12	12
row harv.	6	12	12	12	8	8	6	6	12	12
Length of row (m)	678	701	701	450	758	732	184	163	748	581
Date of hand harvest	10–8	9–28	9–30	9–18	9–30	9–21	9–18	9–29	9–30	9–20
Date of machine harvest	10–23	10–12	10–11	10–9	10–9	9–29	10–9	9–29	10–20	9–21
Replications	3	3	3	2	3	3	2	3	3	3
Rain + Irr (mm/growing season)	693	777	599	762	785	617	597	589	693	584

+ All corn following corn except Bose where corn followed soybeans.

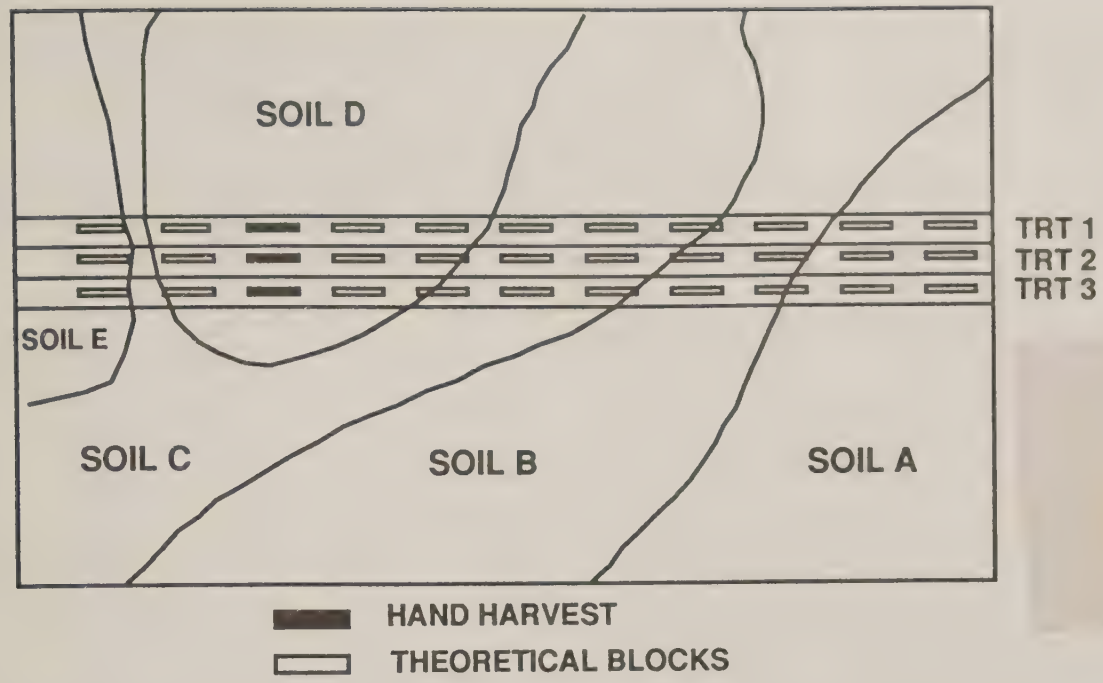

Figure 1. Conceptual drawing of strip test plot layout showing soil types, hand and machine harvest plot areas, and theoretical blocks for one replication.

vest also insured that some estimates of actual yields were obtained for each treatment in case of catastrophic weather or human error.

Results and discussion

The yield data and analyses of variance in Table 2 show the results of the two harvest methods for the irrigated experiments. Inspection of the level of treatment significance, sum of squares for analysis of variance, and coefficients of variation show greater statistical precision with the machine harvest. Of the ten site years, six machine-harvested experiments had significant treatment effects at the 0.10 level of probability. In only one of the hand-harvest experiments was the treatment effect significant at the $P \leq 0.10$ level. In no case was the hand-harvest F value less than the machine-harvest F value when testing for treatment differences (data not shown). Similarly, the error sum of squares was greater for all hand-harvested data. One would expect a slight increase in total sum of squares due to the higher yields in hand-harvest. With the exception of the Shane location in 1988, the total sum of square values was much greater with hand-harvesting than could be attributed solely to increased yield levels. At the 1988 Shane site, the increased sum of squares was due to the machine-harvest treatment sum of squares being very high.

The coefficient of variation, which standardizes the experimental variation for different yield levels, was also less for the machine-harvests for nine of ten experiments; in the tenth experiment the coefficients of variation were equal. This agrees with Fleming et al. (1957) who found that coefficients of variation decreased as plot size increased, using a maximum plot length of 16 m. Thus, the data from machine harvests were more precise than hand-harvest data. To test for significant differences in variability between machine-harvest and hand harvest, the F-ratio of total sum of squares was compared. Using the F-test comparison, six of the ten experiments had significantly greater variation when hand harvested ($P \leq 0.10$). The Shane site in 1988 did not agree with the trend and showed increased variation for machine-harvest due to the high treatment sum of squares mentioned previously.

Our data support the idea that long narrow machine-harvested strips provide a better estimate of actual field productivity than small hand-harvested areas do. The experimental unit (harvest area) for the machine-harvested strip plots was greater than 0.5 ha, compared to 0.0014 ha for hand-harvest. Although soils varied considerably over the length of the field strips, the average yield from the strip, which included many soil types, was less variable than average yield from the small hand-harvested plots. Figure 1 represents an idealized field with markings for soil type, theoretical "blocks," and hand-sampling areas. One may expect that the hand harvest would be more precise since the harvested areas are from a smaller portion of the field and may be on the same soil type. However, soils change gradually and different soils may not be visibly different on the surface.

A possible explanation may be that the longer rows may be conceptualized as providing more "blocks" across each strip compared to the single block from the hand harvest. Since these blocks are harvested together, there is no record of the variation from block to block, only the mean for the strip. These data indicate that the combined blocks represent the treatment on a field better than

Table 2. Yield by harvest method, analysis of variance, coefficient of variation, and F-test comparison for hand and machine harvest at the irrigated nitroge demonstration sites. 1986–1988.

	Hoffman			Schindler	Shane		Smith		Wrede	Bos
	1986	1987	1988	1987	1987	1988	1987	1988	1987	198
					metric tons/ha					
Machine Harvest										
−56 kg/ha	12.38	10.86	10.29	9.24	8.19	8.38	9.87	8.68	11.25	8.05
Recommended N	12.51	10.81	10.64	9.62	8.38	9.68	9.81	8.55	11.77	8.47
+56 kg/ha	12.86	11.39	10.64	10.47	8.34	9.87	10.15	8.68	11.68	8.11
LSD 0.10	.305	.420	.232	.367	.205	.579	1.175	.757	.696	.25
REP (SS)	1.00	.351	.055	.032	.316	1.13	.015	.486	.217	.12
TRT (SS)	.383	.644	.252	1.57	.059	3.94	.134	.015	.474	.30
P	0.06	0.07	0.05	0.02	0.23	0.01	0.71	0.82	0.25	0.05
ERROR (SS)	.122	.233	.071	.031	.055	.443	.324	.134	.640	.08
TOTAL (SS)	1.51	1.22	.379	3.19	.430	5.52	.478	.632	1.34	.51
CV (%)	1.4	2.2	1.3	1.3	1.4	3.6	4.1	(2.1)	3.1	1.8
					metric tons/ha					
Hand Harvest										
−56 kg/ha	13.54	13.91	11.55	8.05	10.94	10.88	11.76	10.96	13.02	8.34
Recommended N	12.53	13.75	13.23	10.37	10.71	10.94	12.13	10.88	12.98	8.36
+56 kg/ha	14.39	13.58	12.05	10.28	10.64	10.73	11.69	10.75	12.47	8.49
LSD 0.10	1.552	.986	1.511	1.497	1.145	.679	2.754	1.761	.965	1.41
REP (SS)	4.921	1.170	1.640	2.616	0.264	0.518	0.110	0.106	0.083	1.82
TRT (SS)	5.186	0.169	4.324	6.933	0.142	0.071	0.205	0.067	0.588	0.03
P	0.14	0.78	0.17	0.07	0.85	0.81	0.90	0.84	0.38	0.97
ERROR (SS)	3.178	1.284	3.012	0.525	1.731	0.609	1.778	0.727	1.229	2.65
TOTAL (SS)	13.28	2.624	8.973	10.07	2.142	1.194	2.099	0.901	1.897	4.51
CV (%)	6.6	4.1	7.1	5.4	6.1	3.6	7.9	3.9	3.8	9.7
Comparison of Machine vs Hand Harvest (Total SS/Total SS)[®]										
F Value	8.8	2.1	23.6	6.1	5.0	4.6	4.4	1.4	1.4	8.8
P	0.003	0.16	0.0001	0.03	0.02	0.02	0.07	0.32	0.31	0.00

[®] F statistic calculated by dividing larger SS by smaller SS.

the single hand-harvest blocks. Our results were implied by Steel and Torrie (1980) when they suggested large experimental units have less variation when compared to small ones and that long, narrow experimental units are more precise than other shapes.

The data presented here challenge the use of the hand-harvest method: Does one take a random sample or attempt to pick equivalent soil types? How large an area needs to be harvested by hand in order to increase precision? One solution could be to hand harvest three or four places in the strip to better approximate the field yield level. This would entail more work and time but may not increase precision, since the three sampling sites may be too small to be representative of the field.

This is a dilemma that may not need an answer if further research indicates that the machine-harvests are more precise since they integrate more of the field and the population of inference. In this group of experiments, only three treatments were considered. Research is needed to determine the critical row length and maximum number of treatments possible to retain the validity of these conclusions.

Tables 3 and 4 present data from similarly designed experiments on dryland. Although the trends noted in the irrigated experiments are still evident, they are not as convincing. Machine-harvest was still more precise, i.e., on average the treatment effects had lower probabilities of happening due to chance alone with machine-harvesting. However, the Hoffman 1986 hand-harvest resulted in significant differences at the 0.10 level while the machine-harvest did not. The F-test for difference in variances between machine-harvest and hand-harvest were not significant. Lack of significance may be due in part to the shorter row lengths in the dryland experiments. Also, variations in soil moisture storage capacity, landscape position, and other site characteristics that affect moisture availability are more pronounced under dryland conditions.

Economic analysis

Declaring significant yield differences allows economic analysis to be performed to determine whether the extra nitrogen increased profit. Increased profit is important since producers intuitively know that use of more nitrogen may result in increased yield. When the yield levels increase with increased nitrogen, the yield differences cannot be overlooked. If researchers and extension personnel show yield increases but attribute the differences to random variation and not to treatments, then the

Table 3. Characteristics of sites used in dryland nitrogen demonstration sites. 1986–1988.

Characteristics	Sites			
	Norfolk	Hoffman		
	Years			
	1988	1986	1987	1988
Soil Type	Moody silty clay	Thurman fine sand		
	Udic Haplustoll	Udorthentic Haplustoll		
Number of:				
rows/plot	12	12	12	8
rows harv.	6	12	12	8
Length of row (m)	94	61	61	61
Date of hand harvest	9–9	10–8	9–28	9–30
Date of machine harvest	10–14	10–23	10–12	10–11
Replication	3	2	2	2
Rain (mm/growing season)	389	533	508	386

producer's confidence in the researcher is reduced. This makes it difficult to convey the most important point of the demonstrations: Using soil sampling procedures and accounting for all sources of nitrogen will increase the producer's profit and decrease potential nitrate contamination.

From the perspective of sustainable agriculture, the data can be used to answer the question of whether nitrogen applications can be reduced below what is recommended based on residual nitrate soil tests. For hand-harvest, the results are easily summarized. For the Schindler site there was reduced yield between the -56 kg/ha rate and the recommended rate. At the other nine sites, there were no significant differences. Since yields were the same, it would be more profitable to apply the reduced nitrogen rate since there would be input cost savings without a yield penalty. However, producers would be skeptical of researchers who attributed the differences to random variation alone. If the researcher attributed the differences to nitrogen without using statistical evidence, then the value of using the scientific method and proper experimental designs would be undermined.

The machine-harvest results show that there were significant differences at 60 percent of the site-years. On these sites, there was a 613 kg/ha yield reduction at the -56 kg/ha rate compared to the recommended rate. On the other 40 percent of the sites, there was a 129 kg/ha yield reduction. Overall, there was a 304 kg/ha difference.

While it is beyond the scope of this paper to fully analyze nitrogen recommendations, a few points should be made in order to show the value of the above information. In order to make an economic analysis of nitrogen rates, both the value of the corn produced and the cost of nitrogen need to be known. Both these values vary over time. The ratio between them, which is the important factor, also changes. This makes a single economic analysis difficult. Table 5 shows the economic impact of a 304 kg/ha yield difference that is a result of a 56 kg difference in nitrogen application. The economic effect is shown for a range of corn values and nitrogen prices.

Table 4. Yield by harvest method, analysis of variance, coefficient of variation and F-test comparison for hand and machine harvest at the dryland nitrogen demonstration sites, 1986–1988.

	Sites			
	Norfolk	Hoffman		
	Years			
	1988	1986	1987	1988
	metric ton/ha			
Machine Harvest				
−56 kg/ha	5.33	8.29	8.71	2.58
Recommended N	5.83	9.70	9.24	2.96
+56 kg/ha	6.22	9.61	9.18	2.39
LSD 0.10	1.01	3.79	1.45	1.60
REP (SS)	0.01	3.63	1.11	0.26
TRT (SS)	1.23	2.49	0.34	0.33
P	0.14	0.30	0.32	0.37
ERROR (SS)	0.72	1.08	0.16	0.19
TOTAL (SS)	1.96	7.20	1.61	0.79
CV (%)	7.3	8.0	3.1	11.8
	metric ton/ha			
Hand Harvest				
−56 kg/ha	5.95	9.37	10.81	2.86
Recommended N	6.21	11.20	10.84	3.46
+56 kg/ha	5.89	10.65	10.53	3.74
LSD 0.10	1.22	1.75	3.13	2.90
REP (SS)	1.16	0.44	2.07	3.81
TRT (SS)	0.17	3.54	0.12	0.81
P	0.74	0.06	0.86	0.44
ERROR (SS)	1.04	0.23	0.74	0.63
TOTAL (SS)	2.36	4.21	0.86	5.25
CV (%)	8.5	3.3	5.7	16.8
Comparison of Machine vs Hand Harvest (Total SS/Total SS)[e]				
F VALUE	1.2	1.7	1.8	6.6
P	0.40	0.29	0.27	0.03

[e] F statistic calculated by dividing larger SS by smaller SS.

Table 5. Effect of yield difference, difference in nitrogen application, nitrogen cost, and corn price on profit or loss due to the additional nitrogen application.

	Price of nitrogen ($/kg)						
	0.176	0.242	0.308	0.374	0.44	0.506	0.572
Price of corn $/metric ton	Difference in yield = 304 kg/ha Nitrogen rate difference = 56 kg/ha						
	Marginal profit $/ha						
117.87	25.74	22.04	18.35	14.65	10.96	7.26	3.56
98.23	19.81	16.11	12.42	8.72	5.02	1.33	−2.37
78.58	13.88	10.18	6.48	2.79	−0.91	−4.60	−8.30
58.94	7.94	4.25	0.55	−3.15	−6.84	−10.54	−14.23
39.29	2.01	−1.69	−5.38	−9.08	−12.77	−16.47	−20.17

Harvest and drying costs have not been included in the above analysis. Typical harvest and drying costs for irrigated corn production are approximately $12.82/metric ton. (Jose et al. 1989)

Prices for nitrogen depend on the nitrogen source. Anhydrous ammonia can be purchased and applied for about $.308/kg N while other sources are $.572/kg. However, nitrogen prices have been as much as double that during the energy crisis. Corn prices vary also depending on the government program and the market. A recent market price would be about $100/metric ton.

Because of the variation in prices, one cannot definitively determine the effect of a 56 kg addition in nitrogen rate on profit. However, the range is from about $8.92/ha increased profit when nitrogen is inexpensive and corn expensive to a loss of $8.14/ha when nitrogen and corn are at 1989 prices.

It should be noted that the recommended nitrogen rates used in the experiment are those based on deep sampling and with other sources of nitrogen taken into account, such as irrigation water. These may be lower than recommendations made without deep soil tests that are based on yield goals alone. The profit and loss shown in Table 5 indicate that if nitrogen price increases due to energy costs or taxation, then reduced nitrogen application will be even more profitable.

Conclusion

With appropriate planning, precision can be increased in order to determine treatment differences that are of practical value to researchers and other potential users of research. Long, narrow strip tests, when replicated, increase statistical precision as a result of representing the population of inference better. Machine harvest of corn was shown to have reduced variability when compared to hand harvest on the same plots. Longer rows provide more "blocks." Since blocks were not measured individually, the variability between them was averaged for each strip. Treatment differences agreed with expected results more often with machine-harvests than with hand-harvests. Further research needs to be conducted to determine optimum row length and to learn how many treatments can be included without affecting statistical precision.

For on-farm research, the implications of this research support the use of replicated strip trials as a means to demonstrate new technologies. Replicating field demonstrations will provide researchers with statistically interpretable data. By having long narrow strips with production-sized equipment, statistical precision will be increased, thereby allowing for greater confidence in the results. Alternative agriculture has used on-farm research to develop new ideas. The data presented here support the validity of these trials and show how the trials can be conducted to maximize their value to farmers and researchers.

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Profits and risks of using crimson clover and hairy vetch cover crops in no-till corn production

Stephen L. Ott and William L. Hargrove

Abstract. *Winter legume cover crops are receiving increasing attention from agronomists and farmers as a source of nitrogen for summer crops. While agronomists are continually providing new technical information on using legumes as a nitrogen source, little is known on the economics of their use. Previous economic research on legume cover crops has focused mainly on budgeting analysis. In the present work, a two-factorial experiment was designed to test the use of legumes as a nitrogen source for corn (*Zea mays *L.) in north Georgia. The first factor was winter cover crop with treatments being crimson clover (*Trifolium incarnatum *L.), hairy vetch (*Vicia villosa *Roth), wheat (*Triticum aestivum *L.), and no cover crop or winter fallow. The second factor was nitrogen (N) fertilizer applied at five different rates: 0, 25, 50, 100, or 200 pounds per acre. For each combination of the two factors, mean yield and yield variance were determined. Results indicated that legume cover crops increased both average corn yield and yield variance. The greater yield variance from the use of legume cover crops increases economic risk. Risk-averse farmers must be compensated for increased profit variance by higher average profits. A safety first method was used to evaluate the trade-off between average profit and profit variance for the risk-averse individual. The results showed that hairy vetch with 50 pounds of N per acre was the best combination of cover crop and fertilizer rate for risk-neutral farmers. For risk-averse farmers, hairy vetch without any nitrogen fertilizer is preferred.*

Key words: nitrogen, legumes, corn, fertilizer, yield, yield variance, economic risk

Introduction

Interest in using a legume to provide nitrogen for a succeeding grain crop is increasing as farmers begin to question the desirability of relying solely on synthetic nitrogen fertilizers (Power, 1987). Organic farmers producing cash grains without livestock need a legume in their rotation to remain as profitable as conventional farmers (Cacek and Langner, 1986). Martin and Touchton (1983) reported that southeastern farmers are becoming interested in using annual legumes in conservation tillage systems. Winter legume cover crops combined with no-till planting provide farmers with an effective soil erosion control method (Hargrove et al., 1984) and offer a potential method for bringing cropland into compliance with USDA's soil erosion tolerance.

With legume cover crops, the fall-planted legume is mechanically or chemically killed in the next spring. The summer row-crop is then no-till planted into the legume residue. The legume decomposes, providing nitrogen for the summer crop. This method has been an effective nitrogen source. Studies in Alabama (Touchton et al., 1984), Delaware (Mitchell and Teel, 1977), Florida (Reddy et al., 1986), Georgia (Hargrove, 1986), and Kentucky (Ebelhar et al., 1984) have shown that legume cover crops can supply most, if not all, of the nitrogen required by such crops as corn (*Zea mays* L.), cotton (*Gossypium hirsutum* L.), grain sorghum (*Sorghum bicolor* (L) Moench), and wheat (*Triticum aestivum* L.).

While extensive agronomic research has been done on the use of legume cover crops, economic research has been lagging. Dobbs et al. (1988), Goldstein and Young (1987), and Helmers et al. (1986) report the economics of growing legumes for nitrogen. In their studies, the legume becomes part of the crop rotation, resulting in a loss of a grain crop harvest. Our focus, on the other hand, is on legumes grown between grain crop harvest and planting. With winter legumes, farmers do not have to sacrifice a grain crop to get organic nitrogen. The few studies measuring the economic desirability of using winter legume cover crops have reported varied results. Frye et al. (1985) found using hairy vetch in corn production to be profitable, but Shurley (1987) found its use to be a breakeven proposition. In grain sorghum production, Ott (1987) reported growing crimson clover to be unprofitable.

The three economic studies just cited focused on average returns. While this information is helpful in assessing the economics of the use of legume cover crops, economic research that incorporates summer grain yield variability is also needed.

The purpose of this paper is two-fold. First, it reports corn yields from an agronomic experiment in Georgia using different cover crops. Then the average riskiness of profit with the use of these different cover crops is examined.

Agronomic analysis of using legumes in Georgia

Experiments were conducted to test the use of legumes as a nitrogen source

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for corn (c.v. 'Pioneer 3165') in north Georgia. The legumes, crimson clover (c.v. 'Tibbee') and hairy vetch (c.v. 'Common'), were compared to using a non-legume, wheat, and no planted cover crop (winter fallow). To each cover crop, five different nitrogen fertilizer rates of ammonium nitrate were applied to provide 0, 25, 50, 100, or 200 lb of actual N/A. Paraquat was used to kill the cover crops with atrazine and metolachlor used for additional control of cover crops and weeds. Each year the stands of corn were good.

Corn yields following the different winter covers for the 1985-1987 growing seasons are presented in Table 1. Corn following hairy vetch had the highest average yield each year for the N fertilizer rates 0 to 100 lb/A. At the 200 lb N/A rate, corn yields following crimson clover and winter fallow in 1985 and following wheat in 1986 were greater than following hairy vetch. For the three-year average, only corn following crimson clover had greater yields than corn following hairy vetch at the 200 lb N/A rate. Corn yields following crimson clover were next highest. Using wheat as a cover crop resulted in the lowest three-year average corn yields. Three-year average corn yields were the greatest at the 200 lb N/A rate for all cover crops except hairy vetch. Three-year average corn yields following hairy vetch peaked at 100 lb N/A, which was the highest three-year average corn yield following any cover crop.

Variance of corn yields can be important in determining which cover crop to use. One major source of corn yield variance is from using four different test plots (replicates) per cover crop - fertilizer combination. Even with uniform agronomic experimental site and equal treatment among replications, each replicate does produce a different yield. Of greater importance, though, is the yield variation caused by weather. During the experiment's three-year period, the rainfall received in July and August varied greatly and was found to be highly correlated with corn yields. July-Augu rainfall in 1985 was 133 percent of no mal, 90 percent of normal in 1986, an only 43 percent of normal in 1987. A erage corn yields followed the same pa tern. Corn yields were the highest i 1985, with 1986 having the second higl est average yields. Thus, three-fifths corn yield variance for each cover cro - nitrogen fertilizer rate combination a explained by the amount of rain that fe during July and August.

Corn following hairy vetch had th least relative yield riskiness (best rankin of coefficients of variation) when con pared at each nitrogen level for each the three years (Table 1). Crimson clove was rated second in terms of relati yield riskiness. Another way to judg relative yield riskiness is to compa coefficients of variation of the highe yield following each cover crop for eac year. Using this criterion, corn followin crimson clover was rated superior in re ative yield riskiness, with hairy vetc second.

Table 1. Mean, Standard Deviation and Coefficient of Variation (CV) of Corn Yield, Following Four Cover Crops, North Georgia, 1985-1987

N rate (lb/a) year	Hairy vetch			Crimson clover			Winter fallow			Wheat		
	mean	std. dev.	CV	mean	std. dev.	CV	mean	std. dev.	CV	mean	std. dev.	CV
	—(bu/A)—		%	—(bu/A)—		%	—(bu/A)—		%	—(bu/A)—		%
0												
1985	181	10	5.5	159	12	7.5	55	17	30.9	46	64	139.
1986	131	21	16.0	128	15	11.7	71	27	38.0	50	12	24.
1987	77	28	36.4	69	29	42.0	46	21	45.7	28	12	42.
Avg.	130	48	36.9	119	43	36.1	57	23	40.4	41	36	87.
25												
1985	182	5	2.7	162	25	15.4	96	18	18.8	81	39	48.
1986	143	18	12.6	127	15	11.8	105	13	12.4	78	17	21.
1987	73	17	23.3	69	31	44.9	50	15	30.0	40	14	35.
Avg.	133	49	36.8	119	46	38.7	84	29	34.5	66	31	47.
50												
1985	190	8	4.2	165	31	18.8	113	19	16.8	145	45	31.
1986	155	6	3.9	136	26	19.1	107	25	23.3	111	19	17.
1987	78	22	28.2	73	36	49.3	61	33	54.1	70	5	7.
Avg.	141	50	35.5	125	49	39.2	93	34	36.6	109	41	37.
100												
1985	198	11	5.6	181	19	10.5	178	16	9.0	127	76	59.
1986	156	7	4.5	162	4	2.5	130	18	13.8	128	13	10.
1987	78	23	29.5	63	36	57.1	74	25	33.8	65	33	50.
Avg.	144	54	37.5	135	60	45.1	128	48	37.5	107	53	49.
200												
1985	188	12	6.4	197	7	3.6	191	10	5.2	158	65	41.
1986	147	8	5.4	147	19	12.9	130	16	12.3	152	4	2.
1987	85	17	20.0	84	18	21.4	71	28	39.4	83	22	26.
Avg.	140	46	32.9	143	50	35.0	131	54	41.2	131	51	38.

Economic analysis of using legumes in Georgia

To isolate the effect of cover crop on profitability, each cover crop—corn system was analyzed under similar production practices. Production started in the fall with cover crop establishment (if applicable) and an application of phosphate and potash fertilizer. The cover crop seed and fertilizer were applied via a bulk fertilizer spreader followed by a light disking. In the spring, a contact herbicide was sprayed to kill the cover crop and any weeds. Nitrogen fertilizer was bulk spread (if applicable). Corn planting was by a fluted coulter no-till planter. The last operation before harvest was a post-emergence herbicide application. Crop enterprise budgets are given in Table 2.

To test the sensitivity of results to price changes, two corn prices were combined with two nitrogen (ammonium nitrate) fertilizer prices. The corn prices used were the 1988 government loan rate of $1.77/bu and target price of $2.93/bu. N prices were the current price of $.28 per pound and 50 percent above the current price, or $.42/pound.

Net returns to fixed resources (revenue above operating expenses) for each corn-nitrogen price combination are presented in Table 3. Hairy vetch with 50 lb of N/A produced the greatest average net return for three of the four price scenarios. The exception was with the lowest corn price and highest nitrogen cost, for which hairy vetch with no nitrogen fertilizer had the greatest net return. For farmers who desire to use no nitrogen fertilizer, the zero nitrogen rate for hairy vetch produced net returns of at least 94 percent of those generated using 50 lb of N/A. In addition, hairy vetch with no N fertilizer generated greater corn profits than any other cover crop.

At low nitrogen prices, the cover crop that ranked second in generating corn net returns was winter fallow using 100 lb of N/A. Its corn net returns were four-fifths of the net returns from using hairy vetch and 50 lb of N/A. When N prices were increased by 50 percent, crimson clover was preferred over winter fallow at the corn loan price and was

Table 2. Corn Operating Costs with Four Cover Crops, North Georgia, 1988[a]

Input	Unit	Quantity per acre	Price $	Cover crops: Crimson clover	Winter fallow	Hairy vetch	Wheat
				($/A)			
Seed corn	lbs	10	1.30	13.00	13.00	13.00	13.00
Clover seed	lbs	20	.95	19.00	—	—	—
Clover innoculant	bag	.4	2.25	.90	—	—	—
Vetch seed	lbs	30	.55	—	—	16.50	—
Vetch innoculant	bag	.6	1.75	—	—	1.05	—
Wheat seed	lbs	50	.125	—	—	—	6.25
Nitrogen	lbs	b	b				
Phosphate	lbs	40	.212	8.48	8.48	8.48	8.48
Potash	lbs	40	.163	6.52	6.52	6.52	6.52
Lime	ton	.25	24.50	6.13	6.13	6.13	6.13
Contact herbicide	gal	.188	35.65	6.68	6.68	6.68	6.68
Surfactant	oz	4	.098	.39	.39	.39	.39
Atrazine	gal	.5	9.22	4.61	4.61	4.61	4.61
Metolachlor	gal	.25	52.26	13.06	13.06	13.06	13.06
Crop oil	gal	.25	7.70	1.92	1.92	1.92	1.92
Tractor & equipment fuel, lube, & repair				12.99	12.79	12.99	12.99
Labor	hr		5.00	11.18	10.85	11.18	11.18
Interest	%		10	5.07	3.41	4.88	3.93
Total[c]				109.95	87.83	107.41	95.16

[a] Excludes drying charge of $.35 per bushel.
[b] Varies, if no nitrogen is applied, then fuel, lube, repair, labor, and interest charges are reduced by $.81.
[c] Totals do not sum exactly due to rounding error.

Table 3. Average Net Return of Using Four Cover Crops in No-Till Corn in North Georgia, 1985-1987

Cover crop nitrogen rate[a]	Prices: Corn $1.77/bu nitrogen $.28/lb Mean ($/A)	Corn $1.77/bu nitrogen $.42/lb Mean ($/A)	Corn $2.93/bu nitrogen $.28/lb Mean ($/A)	Corn $2.93/bu nitrogen $.42/lb Mean ($/A)
Crimson clover				
000	59.39	59.39	197.05	197.05
025	52.24	48.59	190.68	187.04
050	52.54	45.25	197.19	189.90
100	49.77	35.19	204.07	189.49
200	34.29	5.12	199.78	170.61
Hairy vetch				
000	77.46	77.76	227.82	227.82
025	74.31	70.67	228.72	225.08
050	78.17	70.88	241.68	234.39
100	67.77	53.19	234.71	220.13
200	33.32	4.16	195.95	166.78
Winter fallow				
000	−5.60	−5.60	60.92	60.92
025	23.55	19.90	120.49	116.84
050	30.24	22.95	138.61	131.32
100	64.21	49.62	212.24	197.65
200	39.49	10.32	191.14	161.98
Wheat				
000	−35.55	−35.55	12.49	12.49
025	−8.09	−11.74	68.99	65.34
050	44.89	37.60	171.22	163.93
100	27.07	12.49	150.75	136.17
200	32.38	3.22	184.23	155.06

[a] Numbers refer to pounds of nitrogen fertilizer per acre.

equivalent to winter fallow at the corn target price. Unlike hairy vetch, adding N fertilizer did not improve net returns when using crimson clover, except for the corn target price - low N cost price scenario. The N rate that was optimal was 100 lb/A, which eliminated any fertilizer savings over winter fallow. Using wheat as a cover crop always generated less profit than the highest profit from using the other cover crops.

Risk analysis: Theory and method

Although using hairy vetch as a cover crop generated the greatest average profit, it also had the greatest profit variability or risk. How this profit variance affects the desirability of using hairy vetch is dependent on farmers' attitudes toward risk. Risk-neutral individuals are indifferent to risk. They ignore risks in their analyses and select that production practice which produces the highest expected (average) net return. Risk-averse individuals are willing to forego higher average profits in exchange for more certain profits.

There are many ways to evaluate the trade-off between expected profit and profit variance for the risk-averse individual. For this analysis we chose a safety-first criterion of maximizing the lower confidence limit on profits. This method has been proposed by Musser et al. (1981) as a way to incorporate risk in farm management extension programs.

For normally distributed returns, the lower confidence limit of profits as net returns (L_i) can be calculated as follows:

$$L_i = E_i - K\alpha_i$$

where

E_i = expected (average) profits of activity i,

α_i = standard deviation of profits for activity i, and

K = the number of standard deviations required to impose the desired probability that net return in an individual year will be greater than L_i.

By using a statistical table for the normal distribution, one can select a value for K to obtain the desired confidence probability. For example, a K of 0.674 gives a 75 percent lower confidence limit. A 75 percent lower confidence limit means that in three years out of four profits will be greater than the calculated limit.

The yields in our analysis were not normally distributed, but negatively skewed. Instead of using the above formula, cumulative distribution functions (CDF) of corn yields were developed based on experimental yields. Each CDF was determined using linear line segments between the 12 data points (4 replicates x 3 years), with the lowest corn yield being set at 0 percent and the highest at 100 percent. Net revenue CDFs were calculated by multiplying corn yield by corn price and subtracting operating costs.

The use of CDFs implies that both temporal and spatial risks are considered in the analysis. This is appropriate, as both contribute to corn yield variance. Yearly environmental differences, with July-August rainfall being the predominant factor, explained two-thirds of the corn yield variation for the different combinations of cover crops and nitrogen rates. This still leaves one-third of the yield variance due to physical differences among plots, differences that farmers experience in their own fields.

Four arbitrary risk confidence levels were chosen for analysis: 67 percent, 75 percent, 80 percent, and 90 percent.

Risk analysis: Results

The results of the risk analysis reinforce what was found earlier, namely that hairy vetch is the preferred cover crop (Table 4). Like the results based on average net returns, hairy vetch with 50 lb N/A generates the greatest lower limit net returns at the 67 percent confidence level. Hairy vetch without any supplemental N ranks second in preference. As the confidence level increases, hairy vetch with no supplemental N fertilizer becomes the overall preferred cover crop - N combination. The superiority of using hairy vetch without any N for the risk-averse farmer is also demonstrated by the fact it is the only cover crop - N combination that produces a positive lower limit net return at the 90 percent confidence level when corn is priced at the loan rate.

Based on average net returns, winter fallow is preferred over crimson clover with low N prices while crimson clover is preferred with high N prices. For the risk-averse farmer, crimson clover is preferred over winter fallow as a cover crop. At weak and moderate levels of risk aversion (67 percent to 80 percent confidence levels), crimson clover without any N has greater lower limit net returns than those following winter fallow. For the very risk-averse farmer (90 percent confidence level), the lower limit net return for winter fallow and 100 lb N/A is greater than crimson clover's without any N, but is less than crimson clover's with 50 lb N/A.

As with average net returns, wheat remains the least desirable cover crop due to its low net returns. While the net returns to wheat as a cover crop at the 50 lb N/A rate are low, they are stable. Thus, as risk aversion increases, its relative desirability as a cover crop increases. At the 90 percent confidence level with 50 lb N/A, wheat as a cover crop is preferred to hairy vetch with 50 lb N/A and crimson clover without any N.

Conclusions and limitations

Legume winter cover crops, such as hairy vetch or crimson clover, are effective nitrogen fertilizer substitutes for no-till corn. Corn following hairy vetch without any nitrogen fertilizer can produce corn yields equal to those of corn using no cover crop (winter fallow) and 100 lb/A of nitrogen. The substitution of hairy vetch for nitrogen fertilizer is profitable even at relatively low nitrogen prices. Still higher profits can be obtained if 50 lb of N/A is used with hairy vetch. For risk-averse farmers, the preferred cover crop is hairy vetch without any nitrogen fertilizer. Consequently, farmers can reduce or eliminate their nitrogen fertilizer purhcases, improve profitability, and reduce financial risk by planting hairy vetch as a winter cover crop.

Crimson clover requires more nitrogen than hairy vetch to match the corn yields following winter fallow with 100 lb N/A. As a result, the economics of crimson clover are less favorable tha

Table 4. Lower Limit of Net Returns of Using Four Cover Crops in No-Till Corn in North Georgia, 1985-1987

Cover crop-nitrogen rate[a]	Prices: Corn $1.77/bu, nitrogen $.28/lb				Corn $1.77/bu, nitrogen $.42/lb				Corn $2.93/bu, nitrogen $.28/lb				Corn $2.93/bu, nitrogen $.42/lb			
	Risk confidence levels															
	67%	75%	80%	90%	67%	75%	80%	90%	67%	75%	80%	90%	67%	75%	80%	90%
	($/a)															
Crimson clover																
000	47	25	7	−18	47	25	7	−18	175	135	102	57	175	135	102	57
025	26	12	4	−24	22	9	0	−28	142	118	103	52	139	114	99	48
050	18	7	4	3	10	0	−3	−10	134	114	109	97	126	107	102	89
100	20	−18	−28	−36	5	−33	−42	−51	150	81	64	48	135	66	49	33
200	2	−27	−34	−52	−27	−56	−63	−81	141	88	76	44	112	59	47	14
Hairy vetch																
000	48	38	23	7	48	38	23	7	175	156	128	99	175	156	128	99
025	48	10	−1	−20	44	6	−5	−24	181	111	92	57	177	107	88	53
050	51	15	6	−22	43	8	−2	−30	192	127	110	59	184	120	103	52
100	30	−1	−20	−24	15	−16	−34	−38	166	110	76	69	151	95	61	54
200	18	−20	−32	−45	11	−50	−61	−74	169	98	77	54	139	69	48	24
Winter fallow																
000	−22	−23	−25	−36	−22	−23	−25	−36	31	29	25	6	31	29	25	6
025	16	−6	−7	−38	13	−10	−11	−41	107	66	65	9	104	62	51	6
050	17	12	6	−14	9	4	−1	−21	114	105	95	59	107	98	88	52
100	32	17	3	−5	18	3	−11	−19	154	127	102	87	139	113	87	72
200	2	−18	−28	−33	−28	−47	−57	−62	122	87	69	60	93	57	40	31
Wheat																
000	−59	−65	−67	−76	−58	−65	−67	−76	−29	−41	−45	−61	−29	−41	−45	−62
025	−31	−38	−40	−66	−35	−42	−44	−70	27	14	10	−36	24	10	7	−40
050	9	−2	−9	−13	2	−10	−16	−20	106	86	73	66	99	78	66	59
100	14	−3	−27	−80	0	−17	−42	−94	127	97	52	−44	113	82	38	−58
200	−14	−44	−52	−68	−43	−73	−81	−97	100	45	31	2	71	16	2	−27

[a] Numbers refer to pounds of nitrogen fertilizer per acre.

using hairy vetch. At low N prices winter fallow is preferred to crimson clover as a cover crop, but at high N prices crimson clover without any N becomes preferred over winter fallow. The net returns with use of crimson clover as a cover crop without any N are more stable than those associated with winter fallow. Thus, for risk-averse farmers, crimson clover without any N is preferred over winter fallow even at low N prices.

Before one uses hairy vetch or crimson clover as a winter cover crop, some limitations should be noted. It is possible for low winter temperatures (< 5°F) to reduce or eliminate the legume stand, which would reduce quantity of nitrogen produced. In this regard, hairy vetch is preferred over crimson clover as it can tolerate a colder temperature (Hoyt and Hargrove, 1986). However, greater tolerance of cold temperature increases the time hairy vetch requires in the spring to produce adequate quantities of nitrogen. This extra time could delay spring planting. Consequently, these results are limited to the Southeast, Delta, and Mid-South regions of the U.S. Hairy vetch can also prove hard to kill with herbicides and may require a second spraying, a measure which increases costs. On the positive side, legumes as a cover crop can reduce soil erosion and improve soil structure and fertility over time. These risks and benefits were not incorporated in the analysis.

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FROM THE LITERATURE

Abstracted by William Lockeretz

Research reports

Pesticide contamination of groundwaters in the Mahantango Creek watershed. H. B. Pionke, D. E. Glotfelty, A. D. Lucas, and J. B. Urban. *Journal of Environmental Quality* 17:76-84 (1988).

This research examined a 7.4 km-sq agricultural watershed in central Pennsylvania that was about 57 percent cropland, 35 percent forest, and 8 percent permanent pasture. The study surveyed the concentrations of nine herbicides and insecticides in groundwater and attempted to relate the results to cropping patterns and soil and hydrological conditions.

Groundwater samples were collected in December, 1985, and August, 1986, from 20 wells that ranged from shallow (less than 15 m) to deep (greater than 30 m). The pesticides surveyed were chosen to be those that are most commonly used in the area and that have characteristics conducive to being transported to groundwater. The latter include high water solubility, slow breakdown in soil and water, and low adsorptivity in soil. The watershed was a candidate for observing pesticides in groundwater because of its high groundwater recharge rate and because high nitrate levels in groundwater had previously been observed, an indication that groundwater was affected by agricultural activities.

Six pesticides were not found in any wells: alachlor, metolachlor, terbufos, chlorpyrifos, fonofos, and carbofuran. Cyanazine was detected above trace concentrations in only one well. Simazine was found in at least one of the two sampling periods in 7 of the 20 wells, even though it was only known to have been applied near one well. Concentrations of simazine were low (10 to 170 nanograms/liter).

The most widely found pesticide was the herbicide atrazine, detected above trace levels in 70 percent of the wells in at least one sampling period, and in 40 percent of the wells in both periods. Atrazine is the most widely found pesticide in groundwaters nationwide. Concentrations in this study were generally low, ranging from 13 to 1110 nanograms/liter.

The concentration of atrazine, which is applied to corn, was positively related to the proportion of land in corn near the well (taken here as within 100 m of the well on the upslope side). However, the fraction of the atrazine application reaching groundwater was very low, varying among wells from an estimated 0.008 to 0.2 percent.

Not surprisingly, atrazine was highest in areas with continuous corn production. The authors also attempted to relate atrazine concentration to hydrological characteristics of the well site. The only variable that may have been relevant was depth to the water table, with atrazine concentration highest where the water table is shallowest. However, more corn is grown on the flatter bottom areas, which also have the shallowest water tables. Therefore, the relation no longer held when the areas of most intensive corn production were excluded.

Nitrate, chloride, and phosphate concentrations in groundwater were measured in the hope that they were well correlated with atrazine. If so, then these substances could be used to determine easily where atrazine contamination was likely to be a problem. Both nitrate and chloride gave good correlations, but there was no correlation with phosphate, indicating that the latter reaches groundwater through different transport mechanisms. Most nitrate and chloride is associated with corn production. Sources of nitrate include commercial fertilizer, manure, and plow-down legumes, all of which precede the corn crop. Sources of chloride are potash fertilizer applied to corn and to legumes in rotation with corn, and manure. Chloride was a more accurate indicator of atrazine contamination than nitrate, since the latter may be denitrified in the soil. The probability of finding atrazine above trace levels was high when chloride exceeded 3 mg/liter or nitrate-nitrogen exceeded 4 mg/liter. However, the converse was not necessarily true: because of denitrification, high atrazine concentrations sometimes occurred where nitrate was low.

High-yield aquaculture using low-cost feed and waste recycling methods

Gerald L. Schroeder and Steven Serfling

Abstract. *Conventional, low-yield aquaculture methods use earthen, standing water fish ponds that typically are stocked with 0.5 to 2 fish/m^2 and produce 3 to 10 tons of fish/ha/year using refined feeds. At higher fish stocking densities and fish yield, production of metabolites and residues exceeds such a pond's natural recycling capability, so that a higher rate of flushing is required. This wastes water and valuable nutrients and creates a potentially polluting effluent. In an alternative system, by increasing the rate at which the metabolites and feed wastes are microbially processed within the culture system, production rates exceeding 500 tons of tilapia fish/ha/year have been attained with less than 0.5 percent water change daily. In preliminary experiments in this closed bioconversion system, we have replaced all formulated feeds with agricultural residues and fertilizers, which are converted into protein by intense microbial processing. The rate of fish growth indicated that much or possibly all the feed requirements of tilapia grown in this type of closed, densely stocked system can be satisfied by intense cultivation of heterotrophic microbes.*

Key words: stocking densities, tilapia, agricultural residues, microbial processing, fish growth, recycling

Introduction

There is an ever-increasing need to find ecological and economic balance between food production and the environment within which that production is accomplished. At times, this balance is achieved by producing at less than maximum yields per unit area in order not to exceed the environment's capacity to deal with the resulting wastes. Alternatively, production levels can be high, but at a high cost for safe waste disposal. In aquaculture, the latter is often the necessary choice when attempting to meet the increasing demands for fish and shellfish.

An option that takes the best of each alternative is to adjust the environment to increase its capacity to produce the desired end product, while treating naturally the by-products of that production. We discuss here an application of this concept to intensive farming of tilapia fish.

Conventional aquaculture

Aquaculture has conventionally relied on in-pond photosynthesis to supply oxygen, treat nitrogenous wastes, and provide a mix of natural foods. In earthen standing water ponds one meter deep, feed with 25 percent protein supplied at a daily rate equal to 2 percent of the weight of the fish can produce 3 to 10 tons (live weight) of catfish, carp, or tilapia per hectare annually (Table 1). For each kilogram of feed supplied during the grow-out season, 0.5 to 1 kg live weight of fish is harvested. To replace water losses by seepage and evaporation, approximately 1 cm depth of water must be added daily. This amounts to 100 m^3/ha/day or about 3,000 m^3/ton of fish yield (including filling at the start of the season plus daily makeup). Thus, conventional fish farming requires feed at a rate similar to that required by many types of land animals and water at a rate similar to that of many field crops.

To reduce the cost of formulated fish feeds, agricultural residues can be used to fertilize the ponds where aquaculture is integrated with agriculture. This increases the abundance of natural foods useful to the fish (Schroeder, 1986). The ponds accomplish this task by functioning as a sort of "sunlit rumen" in which a mix of autotrophic (e.g., algae) and heterotrophic microorganisms (e.g., bacteria) are produced from the cellulose-rich residues or mineral fertilizers that have been added to the ponds. The pond microbially treats the added matter, recycling it into useful fish foods. With this approach, using only natural foods (no added formulated feeds) in non-aerated ponds, fish yields of 2 to 8 tons live weight/ha/year are attainable (Table 1).

To achieve higher fish yields per unit area, some farms use ponds with circulated water, intense aeration, and feeds containing up to 40 percent protein. Stocking densities in these ponds are increased to 50 to 100 fish/m^2 of pond surface area from the 1 to 2 fish/m^2 typical in standing water ponds. With a daily feeding rate of about 2 percent of the fish biomass, a feed conversion efficiency of 0.5 to 1 kg fish growth/kg supplied feed, and harvest weights of 1/4 to one kg/fish, far more wastes are produced than the pond can process microbially. These wastes are usually drained off daily, along with 10 percent to 30 percent of the total water volume of the pond. This high rate of water exchange is offset by the high rate of fish production (300 to 600 tons/ha/year). Therefore, the demand for water per unit of fish production (approximately 2,000

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Table 1. Characteristics of Conventional and Innovative Aquaculture Systems

	Refined Feeds	Integrated with Agri-culture	Circulated Water	Bioconversion	Biofeed
Status	conventional commercial	conventional commercial	conventional commercial	innovative commercial	developmental
Fish density (fish/m^{-2})	0.5 - 2	0.5 - 2	50 - 100	50 - 100	25 - 100
Nutrient source	cereals & fishmeal	organic residue	cereals & fishmeal	cereals & fishmeal	organic residues & mineral fertilizers
Production (live weight) per unit of refined feed	0.5 - 1	—	0.5 - 1	0.5 - 1	—
tons/ha/year (250 growing days)	3 - 10	2 - 8	300 - 600	300 - 600	?
Typical water use (m^3/ton of fish)	3000	5000	2000	10	10
Water turnover (day^{-1})	0.01	0.01	0.1 - 0.3	.002	.002
Pond material	earthen	earthen	cement or polyethylene	polyethylene	polyethylene
Pond depth (m)	1	1	2 - 3	1	1(?)
Aeration	occasional	none	continuous	continuous	continuous

m^3/ton of fish produced) (Table 1) is similar to that of the less intensive standing water ponds. Only space has been saved. The wastes are now exported from the grow-out pond to the outside environment. Waste treatment ponds must be provided to avoid what would otherwise be a major source of pollution.

An innovative high-yield aquaculture system

In high-density aquaculture (50 to 100 fish/m^2), an alternative to the system just described is to increase the rates at which metabolites and feed residues are microbially processed and recycled within the aquaculture unit. The efficiency of this innovative approach has been demonstrated on a commercial scale by Solar AquaFarms (SAF) in California. The innovation upon which SAF relies to achieve this best-of-both-options (high production and little or no residue buildup) is a series of bioconversion tanks. These tanks aerobically recycle feed residues and metabolites into microbes (bacteria, protozoa, and algae) and carbon dioxide. This eliminates the need for a high rate of water change and establishes a balance between waste production and the microbial processing of that waste.

The use of bioconversion is not new to agricultural waste and sewage treatment systems. In such systems, wastes are pumped through shallow ponds with aeration and water mixing. Exposure to sunlight and oxygen causes nitrogen, phosphorus, and other plant nutrients to be incorporated into algal and bacterial biomass. Much of the incoming organic matter is also incorporated into biomass or respired as carbon dioxide. The soup-like effluent containing a suspension of algae, bacteria, and detritus must then be removed. It is clarified either by holding in settling ponds, by inducing flocculent precipitation through the addition of electrolytes, or by sand filtration.

Solar AquaFarms' bioconversion concept

The crucial difference between con ventional waste treatment systems an SAF's bioconversion method is that th SAF bioconversion system does not at tempt to clarify the effluent. In fact, th goal of the SAF bioconverter is exactl the opposite. The mix of suspended det ritus, algae, and bacteria form a slurr referred to as ODAS, standing for "or ganic detrital algal soup." This ODA is an unwanted by-product of most wast treatment systems. Here, ODAS is a de sired product since it recycles uneate organic and mineral matter back to th fish tanks, but now in the form of mi crobial foods for the fish. This reduce feed and water needs. Instead of the 1 percent to 30 percent daily water re placement rate common in intensiv aquaculture, the rate with the SAF sys tem is less than 0.5 percent. This is ac complished with no decrease in fis stocking density or feeding rate, and feed conversion efficiency either remains un changed or improves.

Although the water replacement rat is very low, water cycles at a high rate once per day, between the fish tanks and the bioconverters. In this way toxic me tabolites, particularly ammonia and ni trite, do not accumulate in the fish tanks. In both the bioconverter and the fish tanks, when dissolved oxygen (DO) falls below 4 ppm, paddlewheel aerators are operated or pure oxygen is injected. About four-fifths of the total tank area is dedicated to fish grow-out and about one-fifth to bioconversion tanks.

At present, the SAF farm has a tota tank area of 3.2 ha, all enclosed in cli mate-controlled, plastic-covered, solar heated "greenhouses." Annual produc tion is 560 tons of tilapia per hectare.

Biofeed aquaculture

The system just described demon strates the practicality of growing fis in densely stocked tanks with minima water change. There remains the task o reducing the cost of feeds. Feed costs i aquaculture, as in most forms of anima husbandry, represent half or more of to tal operating costs. Although a feed ef

ficiency of almost one kg fish growth per kg of supplied feed seems good, this is on a live weight basis. The fish contain approximately 75 percent to 80 percent water, so that on a dry weight basis, the feed efficiency is about 0.2.

A goal of research in progress at SAF is to increase the contribution that natural foods make to fish growth and thereby reduce the need for refined feeds. There are two basic paths to produce natural foods: autotrophic, such as photosynthetic production of algae, and heterotrophic, such as the microbial upgrading of organic matter and subsequent production of bacteria and protozoa. The intensity of a production path can be manipulated by altering the availability of needed minerals or organic matter. However, insolation, the intensity of incident sunlight, is fixed. This sets an upper limit to the photosynthetic production of algae per unit area of pond or tank surface. About 30 g dry weight algal growth/m^2/day is the maximum attainable (Goldman, 1979). In practice, because of shading of lower water layers by overlying algae and other forms of seston, ponds produce ~10 g algae/m^2/day (Schroeder, 1987). At low fish densities (0.5 to 2/m^2), in-pond production of algae can and often does provide much or all of the needed food for fish production. However, even at the theoretical maximum rate of photosynthesis, in-situ algal growth can provide only 5 percent to 10 percent of the food needed when fish densities reach 50 to 100/m^2.

The alternative path for production of natural foods, i.e., the heterotrophic path, does not have the inherent limit of photosynthetic (autotrophic) production. With adequate supplies of organic matter and minerals, plus aeration where needed, extremely high production can be achieved.

Bacteria occupy the lowest niche in the heterotrophic food web. They process whatever organic matter may be present. The bacteria in turn are grazed by protozoans. Above protozoans in the food web are a range of zooplankton, each feeding upon the niche below them. Inherent in going to the next level of a food web is the loss of energy used in metabolic processes and the loss of carbon respired as carbon dioxide. Therefore, animals that are able to graze lower in a food web will have more natural foods available than animals on a higher level. As we discuss in the next section, this makes tilapia an ideal choice for biofeed aquaculture.

Growth, feeding, and digestion in tilapia

Tilapia, commonly known as St. Peter's fish, are native to Africa and the Middle East and have become popular in other parts of the world. Their life cycle is known, and they breed well in captivity. In two months, fry can grow to 7 cm length; and after 6 to 9 months, fish can be harvested at 300 to 500 g each. Tilapia have essentially no intramuscular bones and produce boneless, white fillets.

Tilapia are efficient users of natural foods because in their natural environment they thrive on microbial slimes rich in bacteria and algal derivatives (Bowen, 1982; Moriarty, 1973). Therefore, tilapia culture does not require highly refined feeds. Thus the loss of carbon and energy is less than when nonfoods are upgraded through many trophic levels to form protein-rich, refined feeds, for example for poultry and swine.

The unique digestive system of tilapia allows them to assimilate bacteria, the lowest niche of the heterotrophic food web, even though vertebrates (including tilapia) lack the gastric enzymes able to digest the cell walls of prokaryotes (bacteria, blue-green algae). The first stage in the digestive process in tilapia is based on acidity rather than on enzymes. At the peak of their daily feeding cycle, their stomach pH drops to below 1.4, and values as low as 1.0 have been reported (Bowen, 1982). Most animals have stomach pH values above 2.0. The prokaryotic cell wall remains intact above a pH of approximately 1.8, but the extreme acidity of the tilapia stomach lyses the cell walls of diatoms, bacteria, and blue-green algae. This releases the cell cytoplasm, exposing it to digestion in the tilapia intestines. Eukaryotic plants, including green algae, have cell walls composed of cellulose, which is not broken down by acid.

Current research activity

To exploit this ability to rupture the prokaryotic cell wall, we have started an experimental feeding program that relies totally on single-celled organisms. The preliminary results are encouraging. Mineral fertilizers rich in nitrogen and phosphorus and several trace elements, plus carbon-rich agricultural residues, were supplied to four 300 liter fish tanks at rates that provide 60 g carbon/m^3/day and a C:N:P ratio of ~20:1:0.2. No refined feeds were used. Tilapia fingerlings, 25 to 30 g each, were stocked at densities of 100/m^3. Tanks were aerated to maintain a DO of >4 ppm, except during the 3 hours following supply of the organic matter (twice daily), when intense microbial processing reduced DO by 2 to 3 ppm. Fish gained an average of 0.25 g/day. Yields were 25 g/m^3/day. This is about 10 times greater than the best yields obtained in intensely fertilized earthen ponds, but still 10 times less than what we believe is achievable.

The tanks in these preliminary experiments were shaded. Algal growth was slight. This forced the fish growth to be based entirely on bacteria and protozoa, both of which were abundant in the tank waters. It demonstrated the ability of tilapia to grow on a diet of heterotrophic microorganisms. A similar demonstration, but with considerably lower fish density, has been reported by Avnimelech et al. (1989).

The goal of this research is to have both autotrophic and heterotrophic natural foods present. Because of the inherent limitation on autotrophic production imposed by the available solar energy, the main natural food will have to be heterotrophic. Because of the high oxygen demand associated with intense aerobic bacterial growth, it may be advantageous to have this bacterial growth concentrated in tanks adjacent to the fish tanks and to "feed" the fish tanks with a stream rich in flocs of bacteria and protozoans. In this situation, conditions in each tank can be optimum for their respective organisms.

Implications for the future supply of fish

Aquaculture, either by itself or in conjunction with agriculture, offers a unique advantage in the recycling of residues. The environment in which the fish grows, i.e., the tank or pond, can act as a recycling unit, and the fish can tap into this recycling process by feeding at its lowest niche.

Fish consumption in the United States averages 7 kg/person/year (retail basis). This has been projected to increase to about 9 kg in the next decade, which corresponds to an additional supply of 1.3 million tons (live weight) annually. Ocean yields are leveling, and meeting the increased demand with conventional fish ponds would require around 300,000 ha of ponds and a daily water supply of some 30 million m^3! Alternatively, if this production is in intensively stocked tanks, with total recycling of production residues, these needs are reduced to about 4,000 ha of ponds and 80,000 m^3 water/day, both of which are reasonable. This type of aquaculture promises to be both ecologically sound and economically realistic.

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Oregon passes new organic food law

An organic food law that defines "organic" by a list of acceptable materials and practices has been passed by the Oregon legislature, reports the Oregon Department of Agriculture. The law, which replaces a rule in place since 1973, includes a provisional list of more than 100 substances that growers can use to produce organic products.

The most controversial provision, according to the Department, says that organic food can contain up to 10 percent of the allowable tolerance levels for pesticide residues. Organic advocates had argued the allowance is necessary because most soil has some chemical contamination if the farms were managed in a conventional way even decades earlier. The law gives the Oregon Department of Agriculture authority to levy penalties of up to $15,000 for violations.

Illinois establishes on-farm demonstration project

Farmers at a dozen sites across Illinois are experimenting with the use of low-input techniques as part of a new on-farm demonstration project, announces the Illinois Sustainable Agriculture Society (ISAS). Demonstrations focus on reduction of nitrogen fertilizer and herbicide in row crops. All the sites provide a side-by-side comparison of conventional and alternative cropping systems.

Participating farmers are responsible for design and maintenance of their sites and receive a small per-acre cost-share payment to offset additional costs. The program is funded by the Ruth Mott Fund and is a cooperative effort of the ISAS, the Illinois Department of Energy and Natural Resources, and the American Farmland Trust. For more information, contact the ISAS, c/o Donn Klor, RR 1, Box 58A, Buffalo, IL 62515.

Iowa farmers think farm chemical use too heavy

More than three-fourths of 2007 Iowa farmers surveyed think that farming relies too heavily on chemical fertilizer and pesticides, reports the 1989 Iowa Farm and Rural Life Poll conducted by the Iowa State University Extension Service. Sixty-nine percent of the farmers agreed with the statement that increased use of low-input farming practices would help maintain natural resources. Fifty-six percent said farmers would use more low-input farming methods if more research information were available.

Legume rotations to provide nitrogen are used heavily by 17 percent of the farmers surveyed, moderately by 39 percent, and in a limited way by 33 percent, the survey reported. Twenty-one percent of farmers make heavy use of animal manure, and 34 percent report a moderate use of such manures. Forty-one percent of the farmers said they make no use of integrated pest management programs, while only 3 percent say they are heavy users of such methods.

The survey is conducted yearly by Paul Lasley, Extension Sociologist, and Michael Duffy, Extension Economist. For more information, contact Lasley or Duffy at Iowa State University, Ames, IA 50011.

Comparative local economic benefits of conventional and alternative cropping systems

William Lockeretz

Abstract. *I reexamined five previously published studies that compared the economics of high input conventional crop production systems in various regions to the economics of lower input alternatives that use green manures, cover crops, and more diversified rotations, but no inorganic fertilizers and little or no synthetic pesticides. The original analyses were extended to include estimates of each production system's contribution to the local economy, both directly through farmers' payments for labor and interest, and indirectly through the payrolls and profits of enterprises serving farmers. A similar comparison was also made for high input irrigated and lower input nonirrigated corn production. On a per acre basis, the high input systems' local economic benefits were equal to or greater than those of the lower input systems. However, they were lower as a fraction of total value of production in all but one case, since production was always higher for the higher input systems. Correspondingly, with all but one of the higher input systems, a greater portion of the value of production left the local economy to pay for purchased inputs. This becomes significant if the production system is not sustainable, so that the total productive potential of the area's agricultural resources is finite when integrated over their entire economic life. In such circumstances, the results imply that under the conventional system the local economy will capture a smaller share of the total productive value of those resources.*

Key words: corn production, input level, local economic benefits, sustainability

Introduction

The crisis in the agricultural economy of many regions of the country during the 1980s has caused serious problems not just for individual farmers, but also for communities whose economy depends heavily on agriculture. The latter arise in two ways. First, where farming accounts for a large share of total personal income, depressed farm income means that less money is available to support retail businesses and community services. Second, businesses that supply agricultural inputs suffer because farmers cut down on production-related purchases when times are bad. Consequently, economic distress that initially hurts farmers, as in the much publicized recent wave of bankruptcies and foreclosures, eventually hurts the entire community of which they are a key element (Ginder et al., 1985; Leistritz et al., 1988). Much attention is being given to the economic problems of areas that depend heavily on agriculture. Nationally, about 30 percent of all nonmetropolitan counties are classified as "agriculturally dependent" (Bender et al., 1985). About one-third of personal income is generated by farming in these counties, with a considerable additional contribution from processors, input suppliers, and other enterprises linked directly to agriculture (Petrulis, 1985).

The community-level consequences of depressed farm income mean that the economic attractiveness of a particular production system is not fully reflected in the profits retained by the producer, which is the customary criterion. Different systems can have widely varying local economic impacts for the same profit level. For example, production costs can involve different proportions of resources of local origin, such as labor, compared to inputs brought in from outside the community, such as fertilizer and fuel.

Community-level economic impacts have provided an additional reason for considering alternative systems that make less use of externally purchased inputs than do prevailing practices. Such systems have already been examined from the viewpoints of the profit they return to the producer, their use of nonrenewable resources, their environmental effects, and their relation to federal commodity programs (Papendick et al., 1986; Fleming, 1987; Young and Goldstein, 1987).

Arguments can be made in both directions regarding whether an agriculturally dependent community benefits more from a high production, high input system or from a comparably profitable reduced input system. On one hand, money spent by farmers for many forms of purchased inputs, such as machinery, pesticides, and fertilizers, is largely lost to the local economy. To the extent that reduced input systems replace such inputs by farmers' own labor or by hired labor and management, or simply eliminate them, a greater fraction of the total value of production remains in the community (Heffernan, 1986). On the other hand, a portion of farmers' expenses for inputs bought from local dealers does remain in the local community (wages and salaries paid by the dealer, plus profit if the dealership is locally owned, along with the corresponding items for other local businesses from whom the dealer purchases supplies or services). Concern has been expressed that a shift to reduced input alternatives would im-

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pose a serious hardship for such businesses and would aggravate the economic difficulties already caused by depressed farm income. Similar concerns have arisen regarding federal farm programs that reduce crop output (Petrulis, 1985). For example, Devino et al. (1988), using procedures similar to those used here, have examined how agricultural input suppliers and processors are affected by the reduction in cultivated crops under the Conservation Reserve Program.

To evaluate the conflicting predictions regarding low input agriculture, I have reexamined five economic studies of alternative cropping systems to make rough estimates of their implications for the local economy. These analyses provide an additional way of evaluating such systems along with the more conventional standard of net returns to the producer. I also did a similar analysis for corn production with and without irrigation, which respectively represent high and low input methods within the spectrum of conventional practices.

Systems analyzed

I analyzed possible alternatives to five conventional cropping systems that are important in agriculturally dependent regions of the country: one in the northern Corn Belt, three in the transitional zone between the western Corn Belt and the eastern Great Plains, and one in the Northwest. Table 1 summarizes the major features of these systems. In all but the Wisconsin study, the assumed yields were based at least in part on experimental data. Supporting data were strongest for the Nebraska study, which used 8 years of measured yields for each crop under each management system.

Since none of these systems involves irrigation, I also compared irrigated and non-irrigated corn production in eastern Nebraska. This was done for 1981 because that was the last year in which the necessary crop budgets were issued for portions of a state. This makes the comparison of irrigated and non-irrigated corn more valid than for Nebraska as a whole, since the two are distributed differently around the state.

Because the studies analyzed here were done independently by different investigators, they are not fully consistent in the characteristics of the "alternative" system, a term that has widely varying connotations according to who is using it (Lockeretz, 1988). However, the alternative systems shared many general features (Table 1). All the alternative rotations had more crop species, except in Washington, where both systems had three. All included grasses or forage legumes, either harvested for hay or seed, or raised as green manures or winter cover crops. In contrast, only tilled crops (row crops or small grains) were harvested in the conventional rotations, and only the Nebraska four-year rotation (the same rotation as in the alternative system) included unharvested cover crops or green manures. All the

Table 1. Cropping systems selected for analysis.

Southeastern Wisconsin; Goldstein (1988)

Analysis options chosen: 1987 market prices
Adjustments to original analysis: none

	Conventional	Alternative
System analyzed	3 year cash grain rotation	System 1: 3 year cash grain rotation System 2: 4 year rotation with cash grains and red clover for seed
Crop sequence (* indicates harvested)	Corn*/Corn*/Soybeans*	System 1: Corn*/Soybeans*/Winter wheat*-red clover System 2: Corn*/Soybeans*-winter rye/Winter wheat*-red clover-timothy/Red clover* (seed)-timothy
Manure applications	none	none
Selected inputs (per acre, averaged over rotation)		System 1 / System 2
N-P_2O_5-K_2O (lb)	90-32-32	0 / 0
Herbicides	$22.64	0 / 0
Insecticides	$5.19	0 / 0
Fungicides	0	0 / 0
Labor (hrs)	2.1	1.7 / 1.4

East central South Dakota; Dobbs et al. (1987; 1988) ("Farming System 1")

Analysis options chosen: 1987 market prices; "normal" year crop budgets
Adjustments to original analysis: no land charge, set aside, or deficiency payments

	Conventional	Alternative
System analyzed	3 year rotation, conventional tillage	4 year rotation
Crop sequence (* indicates harvested)	Corn*/Soybeans*/Spring wheat*	Oats*-alfalfa/Alfalfa*/Soybeans*/Corn*
Manure applications	none	2 tons/A (dry basis) on oats
Selected inputs (per acre, averaged over rotation)		
N-P_2O_5-K_2O (lb)	63-20-0	0
Herbicides	$9.61	0
Insecticides	0	0
Fungicides	0	0
Labor (hrs)	1.8	2.3

(Table 1—continued on next page)

Table 1. (continued)

Northeastern South Dakota; Dobbs et al. (1987; 1988) ("Farming System 2")

Options and adjustments: as above

	Conventional	Alternative
System analyzed	3 year rotation, conventional tillage	4 year rotation
Crop sequence (* indicates harvested)	Soybeans*/Spring wheat*/Barley*	Oats*-sweet clover/Sweet clover/ Soybeans*/Spring wheat*
Manure applications	none	none
Selected inputs (per acre, averaged over rotation)		
N-P_2O_5-K_2O (lb)	53-20-0	0
Herbicides	$13.57	0
Insecticides	0	0
Fungicides	0	0
Labor (hrs)	2.1	1.9

East central Nebraska; Helmers et al. (1986)

Analysis options chosen: Manure charged at application cost
Adjustments to original analysis: Average yields 1978-85; 1985 crop prices and production costs; costs from Helmers (private comm., 1989), including fixed machinery costs and overhead not in published study

	Conventional		Alternative
System analyzed	1: Four year rotation, chemicals 2: 2 year cash grain		Same rotation as in conventional system 1, but no chemicals
Crop sequence (* indicates harvested)	1: Corn*/Soybeans*/Corn*/ Oats*-sweet clover 2: Corn*/Soybeans*		Corn*/Soybeans*/Corn*/Oats*-sweet clover
Manure applications	none		8.5 tons/A on corn, 6.0 tons/A on oats
Selected inputs (per acre, averaged over rotation)			
	System 1	System 2	
N-P_2O_5-K_2O (lb)	62-26-0	50-25-0	0
Herbicides	$6.24	$8.83	0
Insecticides	$1.56	$1.56	0
Fungicides	0	0	0
Labor (hrs)	1.1	1.0	1.3

(Table 1—continued on next page)

alternative systems avoided using pesticides and inorganic fertilizers, except that in Washington State pesticides were used at a greatly reduced level. An important characteristic of the alternative systems was their lower production costs and lower output, as will be seen in Table 3. Interestingly, although alternative agricultural systems commonly involve mixed crop-livestock production so that manure is available and forages can be consumed on-farm, only the first South Dakota and the Nebraska alternative systems involved manure applications, and only the former included harvested forage crops. Indeed, the Wisconsin system was specifically intended for conventional cash grain farmers who might wish to switch to an alternative system without having to acquire livestock. The fact that these analyses all deal only with crop production means that a very limited range of alternative systems has been considered. Integrated crop-livestock systems offer much greater opportunity for internal (within-farm) resource flows than do pure cropping systems, and therefore would probably yield very different results from the alternative systems considered here. Unfortunately, no comparable research has been done on alternative crop-livestock systems that would permit them to be included in this analysis.

Considering the characteristics shown in Table 1, of the many terms often used to describe such systems, the label "alternative" can validly be used because these systems differ substantially from conventional practice. "Reduced input" clearly applies as well, and all but the Washington State alternative system would be considered "organic." Whether they can be called "sustainable" must be left open, because the authors did not analyze their environmental impacts, resource consumption, or other factors that determine whether they can continue to be used indefinitely (Lockeretz, 1988). However, we can plausibly assert that the conventional systems are even more patently unsustainable than their alternative counterparts, even though the latter might not be sustainable either. The conventional systems used more chemicals that could contaminate the environment, and they did not use the cover crops and close-grown forages that in the alternative systems are important for maintaining soil organic matter, supplying nitrogen, and conserving soil.

The irrigated and non-irrigated corn production systems analyzed here qualify as higher and lower input systems respectively, but both are "conventional," and obviously neither is "organic." The former is certainly less sustainable than the latter, since along with its greater use of inorganic fertilizers and synthetic pesticides, it extracts water from an aquifer that in some areas is nonrecharging.

Table 1. (continued)

Palouse region, Washington; Goldstein (1986); Goldstein and Young (1987)

Analysis options chosen: 1986 market prices
Adjustments to original analysis: no crop insurance; N fertilizer price $0.19/lb (Goldstein and Young, 1987), rather than $0.29 (Goldstein, 1986).

	Conventional	Alternative
System analyzed	3 year cash grain rotation	"Perpetuating-Alternative-Legume-System" (PALS)
Crop sequence (* indicates harvested)	Winter wheat*/Spring barley*/Winter wheat*/Spring peas*	Spring peas*-black medic/Black medic/Winter wheat* [black medic is seeded with peas at start of first cycle, but reseeds itself in later cycles]
Selected inputs (per acre, averaged over rotation)		
N-P_2O_5-K_2O (lb)	85-39-0	0
Herbicides	$24.02	$7.77
Insecticides	$1.50	$2.00
Fungicides	$10.35	0
Labor (hrs)	1.5	0.9

Eastern Nebraska, corn, 1981; FEDS (1983)

Adjustments to original analysis: land charge excluded; 1977-81 average yields and corn price used instead of 1981 values only

	Irrigated (groundwater, gated pipe)	Nonirrigated
Manure applications	none	none
Selected inputs (per acre, averaged over rotation)		
N-P_2O_5-K_2O (lb)	189-32-8	88-21-3
Herbicides	$6.95	$3.57
Insecticides	$5.23	$2.65
Fungicides	0	0
Labor (hrs)	6.1	3.5

Methods

Adjustments to the production budgets in the original studies

All the studies used here reported yields, prices received, gross revenue, and at least some components of production costs. Production costs always included labor, machinery repairs, overhead, and relevant purchased inputs (seed, fertilizer, pesticide, and fuel and lubrication for machinery, grain drying and irrigation). All labor was charged as though hired at an assumed market rate, although in practice much of this labor would have been provided by the operator and unpaid family members. (This assumption affects the computation of the farm's net returns; however, it makes no difference when computing total local economic impact, since I treat all labor as local regardless of who provides it.) All but the Wisconsin and Nebraska studies also included interest on operating capital, and all but the Washington study included fixed costs for machinery and equipment. All components of production costs mentioned so far were included in the current analysis as originally reported.

A few studies also included charges for crop insurance and crop storage. These items, which were small in any case, were omitted here for consistency. A charge for land, reported in some studies, was also omitted (Table 1). It usually would be the same for the conventional and alternative system (except possibly for some difference under crop share rental), so that omitting or including it would not materially change the comparison of the two; moreover, if the land is owned by the operator or a local resident, the computation of income retained in the local economy would be the same regardless of whether land cost is considered. In the breakdown of returns customary in farm budgets, "net return" reported in Table 3 means the money that is left to compensate the owner-operator for risk, management, and land, plus machinery ownership where so labeled.

Different studies used different values for input prices, wage rates, interest rates, and other economic variables. In part these price differences reflected real variation with location, but in part they arose because different data sources were used, or because the studies covered different years. No adjustments were made for these differences across studies; therefore comparisons are valid only between the alternative and conventional system in the same study.

In some of the original studies, more than one set of economic assumptions were used. Where the results were presented in sufficient detail, for consistency I excluded government program payments, price supports, and set aside requirements. Table 1 shows the choice of assumptions and the adjustments, if any, made for each study.

Computation of the "locally retained" fraction of the budget

In estimating the fraction of each budget item retained in the local community, as reported in Table 2, "local" was defined as encompassing the farm, labor, the source of capital, the last seller of purchased inputs (e.g., the local fertilizer dealer, but not the fertilizer manufacturer or intermediate distributors), and the first enterprise to handle the output (e.g., country grain elevator). Thus all

Table 2. Coefficients for calculating locally retained portion of the value of crop production

Labor	1.00
Interest on operating capital	1.00
Seeds, pesticides, fertilizers	.11
Fuel and lubrication	.02
Machinery repair	.54
Machinery fixed costs	.43
Depreciation	.13
Interest	1.00
Taxes	1.00
Insurance	.13
Farm overhead	.40
Grain elevators	.06

expenses for labor, property taxes on machinery, and interest on operating costs and machinery were considered to be totally retained within the local community, along with a portion of the value of farmers' input purchases and sales of crops.

The last item was computed as follows, using data in the *Census of Wholesale Trade* and the *Census of Service Industries*, 1982, for each relevant business category (e.g., farm supply dealers, farm machinery dealers, farm machinery repair shops). First, payroll was computed as a fraction of sales for each enterprise type. To this was added 0.4 times the excess of revenue over the costs of labor and purchased goods. (This difference equals operating costs other than labor, plus profit.) The value 0.4 as an estimate of the relevant fraction was derived by computing the ratio of payroll to sales for the enterprise category "Business Services" (SIC 73), which includes items such as advertising, data processing, management services, and leasing. This procedure amounts to assuming two things: first, that for enterprises such as fertilizer dealers, revenue not spent on labor (which is entirely local) go for general business services obtained within the local economy; and second, that the labor costs for providing those services are also retained by the local economy. (The process goes on: providers of those services in turn purchase other goods and services, a portion of whose cost remains in the local economy, etc. However, I cut off the calculation one level beyond the enterprises that actually deal with the farmers.)

The computation of the "locally retained" fraction for each input was originally done separately for each state. However, the state-to-state variation was slight. Therefore, I used national data, since these are reported on a more disaggregated basis. This allowed the computations to be done with a more precisely chosen enterprise category for each production cost (e.g., "farm machinery repair shops" rather than just "other repair shops").

Interpretation and validity of the computation of value retained locally

This study takes as a starting point the farm-level costs and returns reported in the original analyses, with the adjustments shown in Table 1. It extends these results by including a component for "additional amount retained in the local economy." Adding this to "net return" yields an estimate of the total locally retained income and profits generated directly by each production system. In effect, this amounts to changing the boundary for calculating net return, which is the difference between money that comes into an enterprise from outside, less the amount that leaves. The boundary now becomes the local economy, rather than the farm. The part of a farmer's production cost that is retained within the community (for example, paid directly to farm laborers or indirectly to the workers at an input dealership), which would be deducted from revenue received by the farm when computing the farmer's returns, is not deducted when computing what might be labeled the community's "net return." (It is not actually called that, because the community is not an enterprise in the conventional sense of the term; I use the label "value retained locally.")

Calculating the portion of the value of farm production that is retained in the local community is a complex matter, to which I have taken a highly simplified approach. First, "local" has been defined functionally, not according to where farmers actually trade. For example, a fertilizer dealer is automatically called local, even though some farmers, especially operators of larger farms, may buy fertilizer in bulk from more distant suppliers (Heffernan, 1986). Somewhat arbitrarily, the computation includes labor hired by the farmer, the payrolls of the enterprises the farmer deals with (plus a fraction of their profits), and an estimated amount for the payrolls of the enterprises that these enterprises deal with in turn. No attempt is made to deal with "multiplier" effects, e.g., further economic activity generated when money paid to workers in turn is spent in the local community.

Second, having specified what is considered "local," my procedure for computing the appropriate fraction of input purchases and crop sales (the coefficients in Table 2) is very crude in several respects. It is based on aggregate data for each class of enterprises serving farmers, whereas the actual figure could vary for different products sold by the same dealer. For example, a dollar's worth of business at the local farm supply dealer will result in $0.11 being credited as retained in the local economy, regardless of whether it is spent on seed, fertilizer, or pesticide. Also, some nonlabor operating expenses incurred by input suppliers and elevators are for items other than local business services (details on the makeup of these expenses are not provided in the Censuses), and they are not necessarily spent at other local enterprises. Finally, the difference between gross revenue and the cost of labor and purchased goods includes, as mentioned, not just operating expenses, but also profits; available data do not permit these two to be separated. The allocation used here would be valid if it happened that 0.4 of profits are retained locally, whereas the true fraction could be anywhere from 0 to 1, depending on what proportion of the enterprises are locally owned.

Therefore, these calculations are not to be interpreted as absolute measures of the local economic impact of a given farming system. However, despite their shortcomings, they are appropriate for comparing two systems at a given location; the same simplified assumptions are applied to both systems in the pair, so that they introduce an error only to the extent that they are more inaccurate for one system than the other. As a measure of the sensitivity of the results to these assumptions, I have done all calculations with the coefficients of Table 2, except for labor, multiplied respectively by 0.5 and 1.5 (in the latter case except for interest on operating capital, where it already was 1.0, its highest possible value). As will be seen in Table 3, this does not qualitatively change the conclusions regarding the differential local economic impact of the two systems in each paired comparison.

Results

The results of this analysis are summarized in Table 3. The first three lines for each study reproduce the findings of the original studies, except for the adjustments shown in Table 1. To the farmer's net returns I add the additional value retained in the community, calculated by applying the coefficients of Table 2 to each component of production costs. The result is the amount retained in the community. The amount by which this is less than the gross value of production is the part of production costs that is not retained locally, e.g., the wholesale cost of materials brought into the community.

As expected, all the alternative systems produced less value per acre, and with one exception also incurred lower production costs, both absolutely and as a fraction of the value of production. (In the one exception, the Nebraska alternative system had lower variable costs than the conventional systems, but its total costs were higher because of higher fixed machinery costs.) Although the conventional systems were more productive, neither class of production system consistently generated higher net returns for the farmer.

Table 3. Crop production costs and returns, and locally retained portion of total revenue. ($/A, averaged over rotation; figures in parentheses are % of value of production; totals may not correspond to details because of rounding.)

Southeastern Wisconsin

	Conventional	Alternative	
		System 1	System 2
Value of production	293	244	220
Production costs	139 (48%)	76 (31%)	64 (29%)
Net return to risk, management, and land	154 (52%)	167 (69%)	157 (71%)
Additional amount retained in local economy	58 (20%)	42 (17%)	36 (17%)
Total retained locally	212 (72%)	209 (86%)	193 (88%)
Low/High estimates[a]	189 - 235	193 - 226	179 - 208
Amount not retained locally	81 (28%)	34 (14%)	27 (12%)

East central South Dakota

	Conventional	Alternative
Value of production	129	109
Production costs	102 (79%)	84 (78%)
Net return to risk, management, and land	27 (21%)	24 (22%)
Additonal amount retained in local economy	45 (35%)	46 (43%)
Total retained locally	72 (56%)	70 (65%)
Low/High estimates[a]	55 - 88	54 - 85
Amount not retained locally	56 (44%)	38 (35%)

Northeastern South Dakota

	Conventional	Alternative
Value of production	116	74
Production costs	101 (87%)	59 (79%)
Net return to risk, management, and land	15 (13%)	15 (21%)
Additional amount retained in local economy	46 (40%)	33 (45%)
Total retained locally	62 (53%)	49 (66%)
Low/High estimates[a]	44 - 78	37 - 60
Amount not retained locally	54 (47%)	25 (34%)

East central Nebraska

	Conventional		Alternative
	System 1	System 2	
Value of production	168	163	157
Production costs	97 (58%)	92 (57%)	102 (65%)
Net return to risk, management and land	71 (43%)	71 (43%)	56 (35%)
Additional amount retained in local economy	50 (30%)	45 (28%)	57 (37%)
Total retained locally	121 (72%)	116 (71%)	113 (72%)
Low/High estimates[a]	102 - 140	99 - 133	92 - 134
Amount not retained locally	47 (28%)	47 (29%)	44 (28%)

(Table 3—continued on next page)

The non-farm value retained in the local economy (beyond the farmer's net returns) was generally lower for the alternative system than for the corresponding conventional system. The total value retained locally was generally lower with the alternative system as well, or at best about equal. Sometimes the lower added local value under the alternative system was enough to cancel its

Table 3. (continued)

Palouse region, Washington	Conventional	Alternative
Value of production	176	118
Production costs	125 (71%)	53 (45%)
Net return to risk, management, land, and machinery ownership	51 (29%)	65 (55%)
Additional amount retained in local economy	43 (24%)	24 (20%)
Total retained locally	94 (54%)	89 (76%)
Low/High estimates[a]	78 - 109	80 - 97
Amount not retained locally	84 (46%)	29 (26%)

Eastern Nebraska, corn	Irrigated	Nonirrigated
Value of production	286	177
Production costs	283 (99%)	143 (81%)
Net return to risk, management, and land	3 (1%)	34 (19%)
Additional amount retained in local economy	109 (38%)	63 (35%)
Total retained locally	112 (39%)	97 (54%)
Low/High estimates[a]	70 - 150	73 - 118
Amount not retained locally	174 (61%)	81 (46%)

[a] Low estimate computed by multiplying coefficients in Table 2 by 0.5, except for labor; high estimate multiplies coefficients by 1.5, except for those that are already 1.0.

advantageous returns to the farmer (e.g., in the Washington State study). However, as a fraction of the total value of production, total amount retained locally was higher for the alternative systems (except for Nebraska, where the alternative and the two conventional cropping systems came out about equal). Conversely, the conventional systems entailed a greater amount of money leaving the local economy, absolutely in all cases, and proportionally except in Nebraska. For corn production in Nebraska, the comparison of non-irrigated vs. irrigated fit the pattern for alternative vs. conventional. This is to be expected, since non-irrigated is a lower output, lower input system, even though it cannot be considered "alternative."

In principle, inclusion of local effects when analyzing the economics of alternative and conventional systems could have shifted the comparison in favor of either type of system. If, as is often asserted, alternative systems require more labor, this would make a positive contribution to the local economy. On the other hand, even though most of the cost of purchased inputs leaves the local economy, some does remain behind, so that systems requiring more inputs could have more local economic benefits.

The latter effect dominated for the systems reported here, since total value retained locally under the conventional systems was always at least slightly higher in absolute amount, and sometimes substantially so. All systems analyzed here involved a high level of mechanization, so that labor costs were not a large enough component of the budget to affect the alternative and conventional systems very differently. In fact, labor costs per acre were often lower with the alternative systems (Table 1), since these systems had a greater fraction of their land in less intensively grown crops, such as small grains and green manures rather than row crops. In other words, switching to one of these alternative systems does not mean substituting labor for inputs; rather, one simply drops certain inputs, adjusts the crop mix accordingly, and accepts a lower level of output in consequence.

Discussion: Extending the results over time

The finding that the conventional systems contribute more to the local economy refers only to current cash flow, which is all that can be analyzed with the studies used here. Ideally, however, it would have been desirable to extend the present findings to take account of future as well as present economic costs and benefits. Until the necessary research has been done some speculation will have to suffice.

The possibility that the results might have been different if calculated over a longer time is suggested by the finding that conventional systems generally contribute less to the local economy than alternative systems as a fraction of the value of production, although their contribution is higher in absolute terms ($/A). This means that while a larger amount of money remains in the local economy with conventional systems, a larger amount also leaves it, both absolutely and as a fraction of total production.

The money that leaves is of no consequence if a system is truly sustainable. As long as a system can continue to contribute more to the local economy, to worry about what leaves it is like seeing the hole instead of the doughnut.

However, what if the system will not be able to carry on forever? The possible reasons are many, such as excessive erosion, deterioration of soil quality, depletion of ground water, intractable pest problems because of pesticide resistance and destruction of natural controls, and contamination of the environment by toxic chemicals. Indeed, the very reason for interest in "sustainable" alternatives is the desire to avoid such problems. With unsustainable practices, there is a limit to the total value that the system will ever produce over its entire future life, whatever its lifetime might be. The faster the system draws upon the resources that support it, the sooner those resources run out. A relevant question, then, is: How much of the total future production will be retained in the local economy?

That is why it is appropriate to focus

not just on how much value a production system creates for its producers and for the local economy, but also on how much leaves. The portion of the value of production that leaves the community in a sense takes with it a portion of the finite resources from which it was derived. Buying more inputs enables these resources to be exploited more rapidly; much of the value of the resulting increase in annual production is exported from the community in exchange for those inputs, with only a fraction staying behind. The last line in each comparison in Table 3 is therefore very significant for the long-term economic well-being of the community, where "long-term" means on a time scale comparable to the economic life of the area's agricultural resources. In contrast, the line labeled "total retained locally" is more relevant to the community's current economic well-being.

We have already seen that a greater fraction of the total value of production leaves the community under the more intensive systems; the significance of this finding depends on whether the amount that can ever be produced over the lifetime of the area's agricultural resources (as opposed to the annual production, which was already given in Table 3) is higher, lower, or the same for higher input compared to lower input systems. Can the more intensive system in each comparison be sustained indefinitely? If so, the preceding discussion is of no consequence since the higher input systems not only return a larger amount to the local community now but can continue to do so. If not, we must ask how much more slowly the resources would get exhausted if they were used less intensively, i.e., under the alternative system. For example, suppose the lower input systems are only slightly more sustainable despite their considerably lower annual production. Their cumulative production will also be much lower. Therefore, in the long run the local economy would still benefit less with lower production systems, even if these systems allow it to retain a somewhat larger fraction of the total.

One possibility is that the cumulative productive potential of a given stock of agricultural resources is fixed. This would be similar to a given mineral deposit, for example, where doubling the rate of production halves the useful lifetime. This analogy is most appropriate for irrigation from a non-recharging aquifer, as with the irrigated corn production analyzed here. For the other causes of non-sustainability, the relation between the resource's lifetime and the rate of extraction is more complex. It seems plausible, however, that the total productive potential of some agricultural resources declines when production is intensified. That is, with intensification, useful lifetime may decline by more than the rate of production increases.

An example of this can be seen from comparing extreme rates of resource depletion. At one end of the intensiveness spectrum, if production is maintained at a suitably low level, soil erosion can be kept low enough to constitute no threat to the sustainability of the system; i.e., the lifetime of the resource can be regarded as infinite. Similarly, pesticide-induced problems, such as ground water pollution, poisoning of wildlife, and damage to beneficial insects, can be eliminated: it is, after all, possible to produce at least something with no pesticides, and, in fact, the output of the non-chemical systems considered here at worst was only fractionally lower than with full chemical treatment. Likewise, with appropriate methods, soil organic matter can be maintained or even increased, soil structure can be maintained or improved, and sedimentation and nutrient enrichment of surface waters can be kept negligibly low. Whether such practices would also be profitable for farmers and whether they would be satisfactory as far as supplying domestic and export markets are important additional questions not considered here. Economics aside, at some sufficiently low intensity of production, the lifetimes of all these resources are effectively infinite. Conversely, this is demonstrably not true once the rate of production exceeds some threshold; indeed, looking at the other extreme of resource exhaustion, some cropping systems have already had to be abandoned or have been seriously threatened. Causes have included depleted ground water in portions of the High Plains (Beaumont, 1985), salinization and inability to dispose of contaminated irrigation drainage in California (Coppock, 1987), and unmanageable pest problems caused by inappropriate pesticide use on cotton in the Rio Grande Valley (Bottrell and Adkisson, 1977).

Unfortunately, the actual comparative lifetimes of the systems examined here cannot be stated quantitatively. Even though the term "sustainable" is bandied about casually regarding systems like the low input alternatives analyzed here, we cannot assert that in fact they can operate forever, which is what "sustainable" is supposed to mean. It is not possible to state whether, if the intensity of production were to decrease from the higher to the lower levels considered here, the total amount that could ever be produced would decline, remain the same, or increase. The previous point about the lower share lost to the local economy under lower input systems is relevant only if total production does not decline.

In summary, high production/high input systems generate an equal or greater immediate local economic benefit than the low input alternatives considered here. However, in capturing this advantage, the local economy foregoes more of the total eventual productive potential of the finite resources that support agriculture. To know whether this finding has serious consequences requires that the economic results presented earlier be combined with currently unavailable quantitative information on the physical and biological sustainability of conventional and alternative systems. Together, these would give us a much more complete picture of their comparative economic benefits, both immediately and into the future.

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RESOURCES

Alternative Agriculture: Growing Concerns, a 19-minute video from the national television documentary on low-input, sustainable agriculture, is $15 (order #VT005) from the USDA, ERS-NASS, P.O. Box 1608, Rockville, MD 20850.

Organic Agriculture: What the States Are Doing, a 39-page summary of programs on sustainable agriculture in 30 states, is $5 from the Center for Science in the Public Interest, 1501 - 16th Street, NW, Washington, DC 20036.

The Importance of Biological Agriculture in a World of Diminishing Resources, the 450-page proceedings of the 5th annual IFOAM Conference in 1984, is now available at half price. The cost is $10 (plus postage) from the International Federation of Organic Agriculture Movements (IFOAM), General-Secretariat, c/o Okozentrum Imsbach, D-6695 Tholey-Theley, West Germany.

AERO's Guide to Sustainable Agriculture in the Northern Rockies and Plains, edited by Nancy Matheson, contains a profile of "sustainable" farms and a directory divided by type of operation. The 100-page book is $7 (including postage) from The Alternative Energy Resource Organization, 44 N Last Chance Gulch, #9, Helena, MT 59601. Also from AERO, for $9.95, the proceedings from its 1988 Soil-Building Cropping Systems Conference.

Communities at Risk: Environmental Dangers in Rural America is a 40-page state-by-state summary by Albert J. Fritsch of rural risks from water and air pollution, soil erosion, land misuse, pesticide contamination, and waste disposal. "As many as 313,000 American workers suffer from pesticide-related illnesses each year," the report says. Copies are $10 from Renew America, 1400 - 16th Street, NW, Washington, DC 20036.

State Policy Issues in Sustainable Agriculture, by Gordon Meeks of the National Conference of State Legislatures, surveys the trends in technology of sustainable agriculture and federal and state policies related to the topic, with particular attention to the 1987 Iowa Groundwater Protection Act. It concludes that research and information sharing are priorities to achieve sustainable agriculture and that fostering this research may be the most feasible avenue for state legislatures. For information on copies, contact Meeks at the National Conference of State Legislatures, 1050 - 17th Street, Suite 2100, Denver, CO 80265, (303) 623-7800.

The Organic Wholesale Market Report from the Organic Market News and Information Service (OMNIS) is a weekly publication with market prices on over 100 crops. For a sample copy, send $2 to OMNIS, P.O. Box 1300, Colfax, CA 95713.

America's Growing Dilemma: Pesticides in Food and Water is a 19-page citizen's guide to the issues from the League of Women Voters Education Fund. The publication gives a quick overview of facts on the use of pesticides, human health effects, sources of contamination, relevant regulations, alternatives to pesticides, and the potential of sustainable agriculture. An action guide and resources are listed. Copies are $4.95 plus $1.75 postage/handling from the LWV Publications, 1730 M Street, NW, Washington, DC 20036.

BioOptions is a new newsletter from the Center for Alternative Plant and Animal Products at the University of Minnesota. The first issue contains information on lupine research, advice on starting an alternative enterprise, summary of multiple publications, and other news. The publication is $5 from the Center at 305 Alderman Hall, 1970 Folwell Avenue, University of Minnesota, St. Paul, MN 55108.

Organic Exchange, a new publication from the Working Land Fund in Vershire, Vermont, is designed to exchange information among organic farmers about new ideas, techniques, equipment, and programs. The first issue (Summer 1989) carried letters from farmers describing techniques for raising healthy livestock, beating weed problems in apple orchards, and more. The *Exchange* reprints helpful clippings and gives other news. This publication joins other Fund projects, which include creating a directory of organic dairy farmers and matching potential farmers with farms. *Organic Exchange* is $15 for 3 issues/year from the Working Land Fund, P.O. Box 249, Vershire, VT 05079.

NOFA Videos is a collection of over 30 video tapes of workshops and demonstrations from the Natural Organic Farmers Association annual meetings. The videos are $15 each and cover composting, growing herbs, nutrition, greenhouse management, soil building, organic pest and weed control, and more. For a complete list, send a self-addressed, stamped envelope to the NOFA Video Project, RFD #2, Barre, MA 01005.

Growing Organically, by Paul G. Lanphere, is a 104-page practical guide for commercial and home organic fruit production by a grower with 20 years of experience. Chapters cover fertility, organic pest control, thinning and pruning, storage and marketing. The focus is on how growing organically affects general fruit-growing practices, and the author says most of his experience lies in growing apples and pears. The paperback is $8.95 plus $1.50 shipping (and 7.5 percent sales tax for Washington residents) from Breathe E-Z Books, 1000 Stiss Canyon Road, Wennatchee, WA 98801.

The Best of the Past: Traditional Sustainable Agriculture in Prince Edward Island, by Wayne MacKinnon and Elinor Vass, is a March, 1989, report on traditional agriculture on this island. The report is based in existing literature and oral interviews with farmers. A 30-page annotated bibliography is included. A limited number of copies are available for $1 to cover postage from the Institute of Island Studies, Extension Department, University of Prince Edward Island, Charlottetown, Canada C1A 4P3.

Herbs 88, and Herbs 89, the proceedings from two conferences of the International Herb Growers and Marketers Association, are available for $30 and $35, respectively. Contact IHGMA, P.O. Box 281, Silver Spring, PA 17575.

Market What You Grow, a practical manual for home gardeners, market gardeners, and small farmers, by Ralph J. Hils. It is available for $9.95 from Chicot Press, Box 53198, Atlanta, GA 30355.

Poison Runoff, by Paul Thompson of the Natural Resources Defense Council, is a 484-page guide to principles and programs for control of nonpoint source water pollution on the state and local levels. It concludes that wide disparity exists in the effectiveness of such programs and suggests a set of basic principles and exemplar programs for guidance. The guide is $33 (including postage) from the Natural Resources Defense Council, 1350 New York Avenue, NW, Suite 300, Washington, DC 20005.

Wasting Assets: Natural Resources in the National Income Accounts, by Robert Repetto, et al, of the World Resources Institute, analyzes the relationship of natural resources to capital in the calculation of national economic data. In many systems, natural resources are treated as gifts of nature rather than productive assets whose value must be depreciated if they are used up, the authors argue. The economy of Indonesia, including its agriculture, is analyzed in depth as a case study. Because of excessive soil erosion, estimates suggest that current increases in farm output in Indonesia's uplands are being achieved partly at the expense of potential future output. The 68-page report is $10 (including postage) from the Publications Department, World Resources Institute, 1709 New York Avenue, NW, Washington, DC 20006.

A Proposed New Structure for Food and Agricultural Policy, edited by Sandra S. Batie and J. Paxton Marshall, contains a series of proposals for economic, land use, and other federal agricultural policies. Primary authors are Howard McDowell, Randall A. Kramer, and J. Michael Price; Paul Barkley and Linda L. May; and Carlisle Ford Runge and Daniel W. Halbach. The papers are discussed by Warren E. Johnson. Each proposal is accompanied by a research-based analysis. The papers were originally presented at the 152nd meeting of the American Association for the Advancement of Science. For copies of the 103-page publication, note its title and number (Information Series 89-1, July, 1989). Contact the Distribution Center, Virginia Tech 112, Landsdowne Street, Blacksburg, VA 24060.

1989 Canadian Directory of Organic Agriculture lists over 500 organic produce growers, supplies, and organizations. It is $10 per copy (postpaid) from Canadian Organic Growers, Box 6408, Station "J", Ottawa, Ontario, Canada K2A 3Y6.

COMMENTARY

CREST farming: A strategy for dryland farming in the Northern Great Plains-Intermountain Region

James R. Sims

Abstract. *In the region concerned, agriculture is conducted under stress from several difficult circumstances. These difficulties include, among others, drought, a limited length of growing season, harsh winters, insect pests and diseases, and weeds. The present paper describes several measures that are taken to combat these problems. Control devices include legume green manure/cereal rotations, use of drought-resistant and insect-resistant varieties, and early seeding of spring grain to cause maturation before the period of maximum drought risk. Recently, a wide range of legumes has been grown on a limited basis in the region, and further progress toward improved legume varieties is being pursued.*

Key words: sustainability, lower input, drought resistance, insect pests, weeds, nutrient deficiencies, nitrogen supply, legumes

Introduction

The enactment of Subtitle C of the Food Security Act of 1985 (PL 99-198) is an indication that the long-developing philosophy behind more sustainable systems of agricultural production is gaining the scientific and political recognition and respectability it deserves. Along with this recognition and respectability, we are seeing more and more conventionally trained agronomists desiring participation in sustainable or low-input agricultural research, extension, and teaching programs. Administrators with similar conventional backgrounds are having to learn the sustainable philosophy to accommodate and effectively administer these programs.

Although it may be adaptable to use outside the region, the strategy outlined in this paper was developed specifically for dryland farming in the Northern Great Plains-Intermountain Region. It is presented for consideration by agronomists, administrators, and producers to encourage them to increase their participation in the development of sustainable, lower input systems.

CREST farming

During more than twenty years of experience in the Northern Great Plains-Intermountain Region, the author has conceived the "CREST farming" concept as a means for dealing with stresses and undesirable factors in agriculture, for optimizing the use of resources, and for minimizing negative impacts on the environment. It is suggested that the concept become the basic strategy for developing more sustainable and lower input cropping or farming systems tailored for specific areas and for individual farms within the region.

The acronym CREST is derived from the words "control," "resistance," "evasion," "sustainable," and "tolerable." Sustainability should be both a goal and a measure of success for cropping or farming systems. At least one of the approaches (control, resistance, or evasion) can be utilized to deal with and reduce the effects of any stress or undesirable factor. For some stresses, all three approaches can be employed. In only a few instances will any single one of the three approaches be totally effective. However, partial effectiveness may be sufficient to reduce some stresses to a tolerable level, particularly when all three approaches can be integrated.

Some stresses and undesirable factors are present every year to a degree that continual application of one or more of the above approaches is required. Some of the factors, such as insect pest infestations, can be tolerated up to some threshold level which must be exceeded before the impact justifies the application of one or more of these approaches.

Before discussing in further detail the concept of "CREST farming," we need to understand what is meant when we refer to a "sustainable system." The following approach, put forth by a group

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of extension agronomists working with Dr. Charles Francis (Agronomy Department, University of Nebraska, 1987), is suggested. According to this group, it is more useful for us to understand intended meanings in a particular situation than to argue about precise definitions. To us, a "sustainable system" is a management strategy which helps producers to choose hybrids and varieties; soil fertility package, including rotations; pest management approach; and tillage and crop sequences in order to reduce costs of purchased inputs, to minimize the impact of the system on the immediate and the off-farm environment, and to provide a sustained level of production and profit from farming.

Applications in different cropping systems

With the scientific community largely organized into highly specialized disciplines focused on rather narrow objectives, many agronomists need to develop an appreciation for cropping systems as holistic entities. Such an appreciation can begin by defining a cropping system as "an aggregation or assemblage of resources joined in planned, regular interaction and/or interdependence operated within various known environments for sustained profitable crop production." "Resources" include natural and human resources, technology, capital, and other systems. "Sustained" implies 1) long-term successful operation, 2) conservation of resources (particularly soil, water, and air), and 3) the flexibility to change commodities, management practices, and marketing strategies. "Profitable" implies that output value exceeds input costs. It also implies optimization of input-use efficiency, whether inputs are purchased (fuel), produced on-farm (legume N), or occur naturally (water).

In order to understand, evaluate, modify, or devise new cropping systems, we need to identify and characterize each part of a system. That is, we need to make qualitative and quantitative analyses of the resources and other component parts of the systems. This includes an understanding of each part, factor, or resource response to the forces and effects of other parts of the system. One must also undertand the effects a single part may exert on any or all of the other parts. Understanding the limitations, uncertainties, and probabilities of a resource having a beneficial effect on the system is paramount in devising and operating a successful cropping system. An example is timeliness of precipitation relative to stage of crop growth.

Cropping systems, in reality, are ecosystems. We cannot forget that they may include undesirable parts or components resulting from nature or man's activities. Drought, pests, and farm program requirements are examples.

Hazards in dryland farming

With an understanding of sustainable systems and an appreciation of the complexity of cropping systems in general, we can turn our attention to the challenge of modifying present systems or developing new ones for the Northern Great Plains-Intermountain Region. To do this, it is necessary to examine the nature of Northern Great Plains-Intermountain Region agriculture and the specific hazards involved. Although there are several important irrigation projects in the region, the majority of the cultivated agriculture in the region is conducted without benefit of supplemental irrigation. In this region the following stresses and/or negative factors may be involved:

Low, erratic precipitation (drought)
Hot, dry July and August (drought)
Limited growing season
Unseasonable frosts
Harsh winters
Significant winter precipitation (positive and negative)
Chinook winds (positive and negative)
Insect pests, diseases, weeds
Nutrient deficiencies
Few crop species (monoculture)
Saline-seep hazard
Erosion hazard
Isolation (positive and negative)

Most people associated with Northern Great Plains dryland agriculture will agree that it is difficult to develop a sustainable system of dryland farming for the region.

In developing the application of CREST farming strategy, one can explore modifications to or replacement of the primary cropping systems now in vogue in the region. These cropping systems include production of winter or spring wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.), and occasionally safflower (*Carthamus tinctorius* L.), with variations of alternate crop-fallow rotations in a strip-cropping configuration. These operations are all based on large quantities of purchased inputs. Continuous cropping and flexible cropping (Sims, 1971; Burt and Stauber, 1975), which were introduced during the 1970's as means to reduce the saline-seep hazard, have achieved only limited acceptance; this has occurred primarily as a result of conflicts with the rigid requirements of the Federal farm programs. Our present systems have been successful in the narrow context of survival. When profitability, erosion, saline-seep, and other environmentally damaging effects are considered, however, they are seen to be beset with difficulties (Ford and Krall, 1979).

Examples of control, resistance, and evasion

All three of these approaches have been exploited to some extent in the development of present cropping systems. From our experiences, we would suggest that "evasion" is the least exploited of the three. Dealing with the hazard of limited water and drought hazard in the region, insect pest infestations, and crop nitrogen (N) needs offers the best opportunities to exemplify these facets of CREST farming strategy. Figure 1 illustrates the following described strategies.

A complete inventory, thorough understanding, and optimal management of the dryland water resource offer the best means of offsetting the potential drought hazard which is always present in dryland cropping systems. Once precipitation has occurred, partial water control can be achieved by various cultural practices. Some examples of controlling the water resource are: 1) summer fallowing to prevent water use

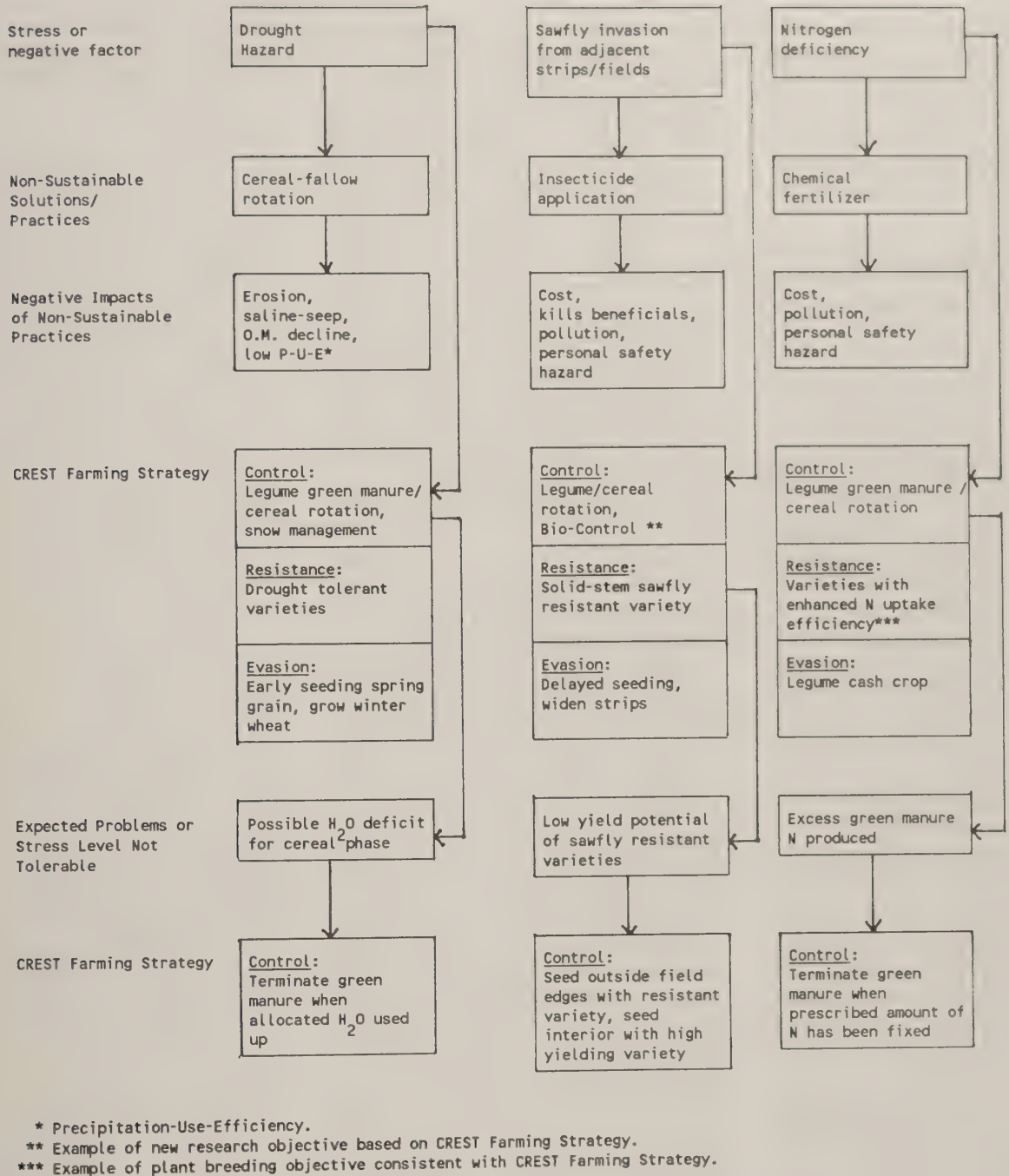
Stress or negative factor
Drought Hazard
Sawfly invasion from adjacent strips/fields
Nitrogen deficiency
Non-Sustainable Solutions/ Practices
Cereal-fallow rotation
Insecticide application
Chemical fertilizer
Negative Impacts of Non-Sustainable Practices
Erosion, saline-seep, O.M. decline, low P-U-E*
Cost, kills beneficials, pollution, personal safety hazard
Cost, pollution, personal safety hazard
CREST Farming Strategy
Control: Legume green manure/ cereal rotation, snow management
Resistance: Drought tolerant varieties
Evasion: Early seeding spring grain, grow winter wheat
Control: Legume/cereal rotation, Bio-Control **
Resistance: Solid-stem sawfly resistant variety
Evasion: Delayed seeding, widen strips
Control: Legume green manure / cereal rotation
Resistance: Varieties with enhanced N uptake efficiency***
Evasion: Legume cash crop
Expected Problems or Stress Level Not Tolerable
Possible H2O deficit for cereal phase
Low yield potential of sawfly resistant varieties
Excess green manure N produced
CREST Farming Strategy
Control: Terminate green manure when allocated H2O used up
Control: Seed outside field edges with resistant variety, seed interior with high yielding variety
Control: Terminate green manure when prescribed amount of N has been fixed
* Precipitation-Use-Efficiency.
** Example of new research objective based on CREST Farming Strategy.
*** Example of plant breeding objective consistent with CREST Farming Strategy.

Figure 1. Schematic of CREST Farming strategy applied to problems inherent to dryland grain/fallow cropping systems.

by weeds and volunteer grain, 2) establishing barriers of tall wheatgrass (*Agropyron elongatum* (Host) Beauv.) (Black and Siddoway, 1976), and 3) maintaining standing stubble on the field throughout the winter period to enhance snow accumulation (Caprio et al., 1986). The effectiveness of each of these varies considerably from one season to another and from one location to another.

Resistance to drought can be incorporated into cropping systems by planting recommended cultivars bred and selected for drought tolerance. Partial evasion can be accomplished by carrying out practices which attempt to mature the crop before the period of greatest drought hazard. In our region this hazard generally occurs during the months of July and August, when evaporative demand is greatest and rainfall drops sharply. Drought hazard may also be avoided by early seeding of spring grains or cool season legumes, by seeding early maturing varieties, and by planting winter wheat rather than spring wheat or barley. Spring grains and cool season grain legumes, such as garbanzo bean (*Cicer arietinum* L.) and faba bean (*Vicia faba L.*), should be seeded as early as

machinery can be successfully used in the field. Each day's delay in seeding will result in a yield reduction of about 1 to 2 bu/A of wheat or barley (Post, 1966), 25 to 60 lb/A of garbanzo bean (Auld et al., 1982; Welty et al., 1982), and 18 to 20 lb/A of faba bean (Sims et al., 1989).

Some control of insect pest infestations can be accomplished by biological methods, judicious use of chemicals, and manipulation of other system components vital to the insect's life cycle. As with drought hazard, the planting of recommended insect pest resistant cultivars can aid in reducing damage. Solid-stemmed, sawfly (*Cephus cintus*)- resistant varieties of wheat offer a good example of this method (McNeal et al., 1985). The evasion approach can also be applied to insect pest problems in some instances. Thus, development of sawfly larvae requires near-maximum stem diameter; but with delayed seeding, spring wheat stem diameter may be too small for larvae when this stage occurs. Reduced yield potential can be a trade-off with these practices. Planting winter wheat instead of a spring grain in areas where grasshopper (*Melanoplus spp.*) infestations are common or expected may be partially effective. Winter wheat reaches maturity earlier and, in some cases, may develop most of the grain ahead of the grasshopper population peak and would present the grasshoppers with a tougher, less palatable food as compared with the more immature, lush spring grain plants.

Nitrogen often is the most limiting nutrient in crop production throughout the region (Sims and Jackson, 1974; Jackson and Sims, 1977). Most present attempts to control the N supply in the soil are based on the application of chemical fertilizers. Although generally effective, use of these forms of N accounts for a significant portion of today's high purchased farm inputs and often contributes to environmental degradation (Francis, 1987). Biological Nitrogen Fixation (BNF) via the legume-*Rhizobium* symbiosis is another means of controlling the N supply in cropping systems. Actually, however, legumes have yet to be exploited in a significant way in dryland agriculture in the Northern Great Plains-Intermountain Region even though they continue to be important components in a wide variety of humid and dryland cropping systems throughout the world (Allen and Allen, 1981; Webber et al., 1976; Graham and Harris, 1982). This is a puzzling circumstance, especially when one considers the variety of ways in which legumes could contribute as a component in dryland cropping systems, e.g., through nitrogen fixation, alternate cash grain and forage crops, or green manure crops, in breaking cycles of disease, insect pests, and weed cycles, and also in helping arrest the growth of saline-seeps to name some.

Early green manure studies

The minor role of legumes in the region's agriculture may have resulted from a combination of circumstances. The relatively low expense of chemical N fertilizer after World War II may have been involved. Conclusions reached following a 1914 to 1951 study of winter rye (*Secale cereale* L.), field pea (*Pisum sativum* L.), and sweetclover (*Melilotus officinalis* Willd.) green manure-small grain rotations with fallow-small grain as the control (Army and Hide, 1959) may also have been influential. The results of this study led the authors to conclude that the three green manures had no effect or a depressing effect on small grain yields in the following year as compared to ordinary fallow. It was concluded that the main effect of the green manures was to reduce the water available to the later grain crops. Based on their understanding of the data, the conclusions were correct. However, their study was either ahead of its time or terminated 20 or 30 years early. Although legume green manures may impart several beneficial effects on ensuing cereal crops, the primary benefit is the release of symbiotically fixed nitrogen. The legume green manures in that long-term study had little chance of improving wheat yields compared to ordinary fallow for several reasons. First, the soils involved, and most soils in the region, had not yet become N deficient as they are today. Organic matter had begun to decline by the 1950's but still provided ample N to meet the needs of wheat yield potentials of that era. Also, the management of the legumes in these early studies was questionable, since one passage from the report suggested that when the green manure crops were not successfully established there was invariably a good crop of Russian thistle (*Salsola kali* L.) to plow under. Other possible factors leading to poor results in these experiments include inefficient storage of winter precipitation, late seeding, poor timing of plow down, and a lack of nodulation. The latter continues to be a problem in dryland legume culture today, this especially with small-seeded legumes. All these factors substantiate the authors' conclusion that the main effect of the green manures was to reduce the water available to the ensuing grain crops.

CREST farming strategy

As was mentioned earlier, small grain crops grown on the region's soils have responded to additions of N fertilizer since about the mid-1960's. That being the case, they should respond to legume N (Sims et al., 1985; Welty et al., 1988). The successful use of legume-cereal rotations to control N supply in the region would depend on the adaptation of some legume species to the various production areas in the region and finding a solution to the problem of reduced available water for the ensuing small grain crop. Recently, a wide variety of legume species have been successfully grown in the region (Sims et al., 1985; Welty et al., 1988; Sims et al., 1989) and several more show promise in early tests.

As was indicated earlier, with certain cultural practices we can exercise some control over the dryland water resource once the water has fallen on the field as rain or snow. With experiments now underway at the Montana Agricultural Experiment Station, we are learning to control water use by the green manure crop. In these experiments, a predetermined amount of the water has been allocated to the growth of the green manure crop. When the green manure crop has consumed its allocation of water, its growth is terminated by cultivation or

with an herbicide. In the drier areas, e.g., those with 14 inches or less of annual precipitation, we may be able to allocate only 3 inches of water to the green manure. In the area with 14 to 17 inches of precipitation, perhaps 4 inches of water can be allocated; and in the areas with over 17 inches of precipitation, 5 inches or more could be allocated to the green manure.

Evapotranspiration (ET) of water by the green manure crop can be determined by monitoring rainfall and depletion of soil water. The amount of soil water stored in the root zone can be readily determined in many soils by taking cores at seeding time. Subsequent sampling can provide the needed soil water use data. It is entirely possible for meteorologists to develop methods for producers to use to estimate ET from pan evaporation data (Doorenbos and Pruitt, 1974; Jensen, 1973), this on a practical field basis (Sims and Jackson, 1971). Another method for estimating green manure crop ET can be based on cumulative water use curves (Brown, 1971). This would require that agronomists develop a series of water use curves as a function of time and/or growth stage for various legume species and specific agroclimates. The next step to precise control of water use by the green manure would be to seek legume species with the greatest water use efficiency in terms of nitrogen fixation and biomass production at the three levels of allocated water.

The N fixed by the legume green manure crop can also be controlled to a predetermined amount. The quantity of N which the green manure legume is allowed to fix should be based on the anticipated need of the ensuing non-legume crop and the N expected to be made available from soil organic matter. Allowing the green manure legume to fix only a predetermined amount of N will help prevent possible contamination of shallow ground water with nitrates, in addition to supplying the ensuing crops' N need. Such contamination would be a distinct possibility if a green manure crop containing N much in excess of the ensuing crops' need was incorporated into the soil. Control of the amount of N fixed by the green manure legume can be accomplished by monitoring the biomass production and N content of the plant as growth progresses. Methods for monitoring biomass production and the N content of plants have been at hand for a number of years. Many of these methods are practical for use by producers and agency advisors as well as by scientists. Determining the amount of biomass standing in the field could be as simple as clipping, drying, and weighing all of the legume top growth inside a ring of 34 1/2 inch radius from several locations in the field. The average dry weight in ounces multiplied times ten equals pounds per acre of biomass. Also, as long as seeding rate and row spacing (plant population) and variety selection are kept in the range of calibration, plant height may be a useful index of biomass production.

Most laboratories serving agriculture are capable of rapid analysis of total plant N by the use of auto analyzers involving wet chemistry or near infrared spectroscopy. Legume species vary in their N fixation capabilities. Thus, research agronomists can aid in fine tuning this approach by characterizing differences in adapted legume species for biomass accumulation and N fixation as a function of time or growth stage. Data of this type are presently available for some cultivars of some species in which shoot weight (biomass production) and percent N have been recorded as a function of time or growth stage. It may only need to be presented in a different format to become useful for management decisions. A series of curves relating biomass and/or N accumulation to time and/or growth stage may suffice in many instances. This approach and the use of legume green manures in general are predicated on the assumptions of an actual deficiency in available soil N and effective nodulation of the legume.

Concluding remarks

Designing sustainable, dryland cropping systems for the Northern Great Plains-Intermountain Region is difficult. The CREST farming concept as here outlined and explained offers a new strategy for optimizing the use of the region's resources and dealing successfully with the stresses and negative factors associated with dryland farming, at the same time minimizing negative impacts on the immediate and off-farm environments.

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BOOK REVIEWS

The Environmental Effects of Conventional and Organic/Biological Farming Systems. 1988. By C. Arden-Clarke. Vol. 1: Research Report RR-16. Part I: Soil Structure and Erosion; Part II: Soil Ecology, Fertility, and Nutrient Cycles. 109 pp. Vol. 2: Research Report RR-17. Part III: Pest Control Strategy Impacts on the Crop Ecosystem; Part IV: Farming Systems Impacts on Wildlife and Habitat. 156 pp. Political Ecology Research Group, 34 Cowley Road, Oxford OX4 1HZ, England. Typewritten, spiral bound. Price in U.S. (2 vols.): $56.50 air; $50.00 surface.

This two-volume set offers the clearest, most comprehensive, and most informative review of the environmental implications of organic farming I have ever seen. Arden-Clarke is to be credited for presenting an astonishingly large amount of material in a well-organized manner that preserves a coherent overall structure without stinting on the details. He manages to maintain a course between the two extremes that often detract from the value of lengthy reviews: the "catalogue" approach that simply strings the specific citations together with little attempt at relating them to the larger picture, and the overly interpretive approach that selectively draws on the literature to reinforce the reviewer's conception of the topic, giving readers insufficient opportunity to form their own synthesis.

In part, he achieves this by an intelligent organizational scheme, helped out by appropriate cross-referencing among sections. Necessarily, the large amount of detail must be classified into categories of manageable size. However, an overly dissected treatment would be especially inappropriate for discussing organic systems, which so often involve interrelationships among phenomena that in conventional systems may be regarded as completely disjointed. The generous use of cross-referencing reminds the reader of these interrelationships while allowing the material to be presented in digestible chunks. Each of the four major sections begins by describing a category of problems that organic systems are intended to ameliorate, going from there to an evaluation of the seriousness of the problems (primarily in Great Britain) and an explanation of the relevant differences between organic and conventional management methods. This is followed by a detailed review of the literature, organized into units that follow each other in a logical, readily graspable sequence. The literature citations are mainly to British sources, but North American and European sources are well represented too. Each section ends with a summary of the environmental differences between organic and conventional systems and recommendations for further research.

The range of topics covered is very thorough, ranging over a much wider ground than is common in single-author reviews. Major areas include: Soil erosion's effects on yields and its off-site environmental costs; biological, chemical, and physical effects of fertilizers on soil ecololgy and nutrient cycles; effects of pesticides on crops, natural pest enemies, and other non-target organisms; agroecosystem diversity; and effects of farming systems on wild flora and fauna, especially wildlife habitat.

Unfortunately, a review of this kind is necessarily hampered by the inadequate research attention given so far to true organic systems. Arden-Clarke deals with this shortcoming by taking great care to discuss how confidently each conclusion may be stated. Sometimes, an important environmental difference between organic and conventional systems can be asserted unequivocally; the spectrum ranges through various levels of tentativeness to some areas where all that can be said is that, based on general principles, it is plausible to speculate that the two systems will have environmental effects that differ in such-and-such a way. Overall, he concludes that, regarding most environmental effects, organic systems are substantially more desirable. I regard his summaries and conclusions as well justified by the literature reviewed and presented with reasonable balance and appropriate qualifications.

A particularly valuable aspect of this work is that Arden-Clarke recognizes the difference between a study of an

organic farming *system* and a study of certain *practices* that often are used in organic systems. Unfortunately, the relevant literature has much more of the latter, given the relative non-interest in organic farming until very recently. Thus while organic farmers tend to use livestock manures more than conventional farmers, for example, this does not mean that any study that deals with manure application necessarily is relevant to a comparison of organic and conventional systems. This is an important point that is lost on many investigators in the U.S. and elsewhere, often to the detriment of the organic system, regarding both its productivity and its environmental impacts. Arden-Clarke reminds us several times that a true organic system must be designed as a total farming system and that the individual practices are then chosen to fit within this larger conception. Thus, he criticizes British work on integrated pest management as "totally inadequate" because "merely tinkering with a few cultural practices within the framework of a conventional farming system will achieve little, since these systems are fundamentally flawed."

I could readily recommend this work just for its having gathered a large amount of material on an important and interesting question. However, it does much more than that. I have rarely seen a review of so broad a topic that interprets, evaluates, and synthesizes the literature in such an understandable and intelligent manner, yet without the author imposing himself too assertively between the reader and the raw material. This work stands as a major contribution toward developing a much more thorough understanding of the respective merits of organic and conventional systems. — *William Lockeretz, Research Associate Professor, School of Nutrition, Tufts University, Medford, MA.*

Soil Fertility and Organic Matter as Critical Components of Production Systems. 1987. SSSA Special Publication Number 19. R. F. Follett, J. W. B. Stewart, and C. V. Cole, Editors. Soil Science Society of America, Madison, Wisconsin. 166 pp. $18.00, members; $22.00, non-members, paper.

This book consists of nine articles by twenty co-authors on the dynamics and role of soil organic matter in soil fertility. Presented as symposium papers at the 1985 Soil Science Society of America annual meeting, the unindexed articles review the influence of technological advancements on the complex interactions of farm management and climate with physical, chemical, and biological soil factors.

Sufficiently comprehensive for all but the most omniscient research scientist are the discussions of how fertility is affected by soil and climate; soil management and conservation practices; utilization of nutrients in soils and fertilizers; controls on nitrogen, phosphorus, and sulfur dynamics; available technical support systems and advisory services; and organic matter and nutrient cycling information in simulation models.

Alternative agriculture advocates will find something useful in each article, beginning with that of Stewart, Follett, and Cole, who write that "Natural systems have evolved in a manner that conserves nutrients.... Crop production systems that mimic natural systems in terms of lack of soil disturbance and return of crop residues to the soil help maintain the synchrony of nutrient cycling processes and minimize nutrient and organic matter losses."

Acknowledging the influence of soil and climate on crop yields and fertilizer requirements, Arnold and Jones state that simulation model accuracy is only as good as the data on soil, climate, and management. They recommend simulation models such as EPIC (Erosion-productivity impact calculator) to evaluate previously untested combinations of management, soil, and climate, thereby reducing the amount of site-specific research needed to assess improved agricultural technology on soil erosion and the effects of soil erosion on crop productivity.

Follett, Gupta, and Hunt enumerate plant nutrient resources and assess the impact of management practices on soil nutrient losses and environmental pollution.

Relating soil management systems to soil and fertilizer nutrient availability and cycling of plant nutrients, Doran and Smith propose additional research that will achieve several purposes: determine long-term effects of management systems on organic matter dynamics; consider biological activity, mineralization rate, and physical-chemical function in soil structure studies; determine the optimum balance between organic matter exploitation and its value as a conditioner of the soil environment; and improve the direct measurement of nitrogen transformations in the field.

McGill and Myers effectively use architectural models at the molecular, organism, pedon, and field levels to examine soil and fertilizer N dynamics and to determine the safe and efficient use of N fertilizer.

Reviewing the influence of soil phosphorus and sulfur distribution processes on bioavailability in different soils and climates, Stewart and Sharpley point out the need to understand P and S cycles and improve P and S soil test methods that do not take account of the contribution from mineralization of organic forms and past management history.

Stressing the importance of technical support systems to the agricultural industry, Olson and Beaton suggest that commercial, university, and other advisory groups maintain open channels of communication to avoid excessive environmental pollution for which agriculture likely would be blamed.

Ward, Halvorson, and Wisiol recommend the use of computer models that include all crop production factors to develop uniformity that will reestablish the credibility of fertilizer recommendations by soil testing laboratories.

Cole, Williams, Shaffer, and Hanson conclude with a description of several crop production simulation models and challenge soil scientists to provide information on transformations and flows of nutrient and organic matter

for the new technical tools.

True to the book's title, the articles emphasize mainly the chemical fertility aspects of organic matter dynamics. Only tangentially do the authors expound the remarkable influences of organic matter on soil physical properties that improve water-absorbing and water-holding capacities.

As extensive as are the lists of references, few cite works not written in English, and fewer than ten are older than thirty years. Conspicuous by their absence are references to the thirty-year Haughley Experiment in Suffolk, England, and names of prominent European organic and Biodynamic agriculturalists such as Rudolf Steiner, Sir Albert Howard, R. F. Milton, and Lady Eva Balfour, and of the Americans F. H. King and William Albrecht. Since they stress *recent* technological and computer modeling advances in production agriculture, the authors may be forgiven for these omissions.

However, I am not so conciliatory regarding the quality of writing and editing for overall readability. Considering the efforts expended in research and preparation of these review articles, it is unfortunate that poor readability will unnerve many readers who are unfamiliar with current jargon.

Ironically, the reading difficulty stems both from using and misusing the Soil Science Society of America's (SSSA) own *Publications Handbook and Style Manual*. Using required SI (Systeme International d'Unites) units such as Gg (Gigagram) in place of more familiar English or metric units illustrates the first transgression. If the SSSA expects others to read publications containing SI units, it should include either a glossary of terms or a conversion table for reduction to more familiar units.

Examples of SSSA Style Manual infractions include frequent violations of the rule restricting "which" to nonrestrictive clauses and inconsistent use of hyphens with multi-syllable noun unit modifiers. Correcting these misjudgments and using shorter sentences and fewer passive and "state-of-being" verbs would dramatically reduce Flesch-Readability values and improve comprehension. The first article's 23-word opening sentence, which should entice the reader to read on, fails its mandate with a difficult-reading Flesch value of 9.8, where 7.5 is the lower limit of the academic and scientific category.

Although the SSSA Division of Soil Microbiology and Biochemistry is a cosponsor, holistic enthusiasts will find few American references to microflora and mycorrhizae, or the research of "wholes," a need that the Haughley Experiment demonstrated nearly twenty years ago.

The Soil Science Society of America is to be commended for this response to the need to scrutinize doctrines developed before the current emphasis on reduced tillage. Having taken this first step, it will be less difficult to seek solutions to problems of operators exploring additional methods of reducing inputs. To accomplish this, a more fully ecological investigation of the "wholeness" of the climate-soil-plant-animal-man food chain will need to be initiated by the same SSSA divisions that sponsored this publication (Soil Fertility, Soil Chemistry, Soil Microbiology and Biochemistry, and Fertilizer Technology and Use) plus other divisions of the Soil Science Society of America, the American Society of Agronomy, and the Crop Science Society of America.

By so doing, these societies will demonstrate their concern for long-term agriculture and their recognition of the finite limits of soil, water, and air. As only they can do, they should also relentlessly charge their members to seek ways to maintain, improve, and extend the usefulness of these essential natural resources. -- *Orville W. Bidwell, Professor Emeritus, Department of Agronomy, Kansas State University, Manhattan, KS.*

Good Farmers: Traditional Agricultural Resource Management in Mexico and Central America. 1987. By Gene C. Wilken. University of California Press, Berkeley, California. 302 pp. $45.00, hardcover.

Gene Wilken has made a valuable contribution to our understanding of the role that local, indigenous knowledge plays in meeting the demands for food, feed, and fiber in much of the developing world today. This information is of immediate importance. Traditional farming systems are rapidly changing in all areas of the world as economic, social, and political pressures and the availability of new technologies promote the increased adoption of modern agricultural practices. Ecologically sound, locally adapted production based on local inputs is being replaced by an increasing dependence on costly external inputs to maintain productivity. Many authors have called for either the study or preservation of traditional practices, but very few have had the opportunity to go into the detailed, first-hand analysis Wilken has. Even fewer have made this information so readily available to a broad audience.

Organized into thirteen very readable and abundantly illustrated chapters, this book reviews traditional agricultural resource management in Middle America. Examples are drawn from his own extensive field work, mostly in Mexico and Guatemala, and emphasize sophisticated, labor-intensive methods that demonstrate the potential of traditional technology. He presents data that are both descriptive and quantitative, providing the reader with an excellent balance between a general overview and a detailed research report. Most important, his evaluation of each resource management system is based less on yield output data and more on the farmers' evaluations of appropriateness for local environments, resources, and cultural preferences. Wilken's own opinion on how or why each system functions is evident, but it is refreshing to be able to see and hear his point of view balanced (and on occasion even contradicted!) by the farmers' opinions as well.

Each chapter examines how a different resource is managed. The initial focus on energy quickly points out how traditional systems are almost unique in today's agriculture with their ability

to utilize the renewability of human energy. Soil resources are then examined, from intricate local classification schemes to the use of organic and inorganic amendments for soil management. The value of cover crops, manures, and rotations are learned by using them rather than having to be relearned as they are in much of the developed world today. Two chapters examine the complexities of slope and soil surface management systems that have been developed by traditional farmers. Check dams, terraces, raised beds, and mounds all are among the practices used in Middle America. Individual farmers have shown truly remarkable patience in continuously managing such systems.

The largest section of the book is devoted to the management of water resources. Water is deliberately managed to take full advantage of everything from intermittent rainfall to more permanent surface and subsurface systems. Both excesses and shortages of water are examined. The engineering involved in the construction of the *galeria* tunnel system in Puebla, Mexico, for example, is a marvel, as is the complex social structure that keeps it going. It is no wonder that modern agricultural development specialists, with training that rarely deals with such complexity, have had so little luck in such regions. Two final chapters focus on many of the intricacies of microclimate and space management, again revealing the considerable depth of understanding found in traditional systems.

Wilken concludes by discussing the future of traditional agricultural resource management. Although he stated initially that the book's purpose was not to dispel myths about traditional agriculture, several come away very scarred by his treatment. For example, although traditional farms have little capital equipment, substantial labor may be invested in structures for managing resources. Labor may actually be expended to save labor. Also, traditional agriculture is not a purely ecological matter. Its social and economic components can be extremely complex, and the practices can be abandoned if these components change. Traditional management methods are not just anachronisms of dubious value preserved from the past. Instead, they are agronomically and ecologically sound and are based on a thorough understanding of local conditions and plant requirements. Therefore, they deserve close examination by the scientific and development communities.

Wilken admits that his book examines only a portion of the world where traditional agriculture is practiced. He also admits that he doesn't cover that region thoroughly since each localized river drainage system often has its own particular set of practices. The practices cannot be generalized since each is unique. Moreover, as Wilken points out, currently there are distressingly few generalizable methods, analyses, or theories for studying them. His attempt to place the study of traditional agriculture into an interdisciplinary ecological and cultural framework is an important step that will make the book useful to a very broad audience. The fact that some traditional systems have functioned for as long as they have, with some dating well back into prehispanic times, suggests that there is much to learn from these systems that can contribute to the current search for the basis of sustainability in agriculture. Once again it seems that the farmer is the real teacher. -- *Stephen Gliessman, Director, Agroecology Program, University of California, Santa Cruz, CA.*

Missouri forms center for sustainable agriculture systems research

A new center to coordinate research and education on low-input, sustainable agriculture has been established at the University of Missouri in Columbia, announces coordinator John Ikerd. Its objectives are to provide links among priviate and public agencies and individuals within Missouri and to coordinate the university's activities with the federally funded Low Input/Sustainable Agriculture (LISA) Program. For more information, contact Ikerd at the Center for Sustainable Agriculture Systems, College of Agriculture, University of Missouri, 200 Mumford Hall, Columbia, MO 65211.

LETTERS TO THE EDITOR INVITED

The AJAA welcomes letters, short or long, commenting on articles in this journal or sharing ideas likely to be of interest to other AJAA readers. Since our space is limited, we do reserve the right not to publish all letters or, at times, to publish only excerpts from them. To take part in this exchange of ideas, write to: Editor, AJAA, 9200 Edmonston Road, Suite 117, Greenbelt, MD 20770.

UPCOMING EVENTS

January 12-14. Ecological Farming Conference, sponsored by the Committee for Sustainable Agriculture (CSA), in Asilomar, California. Workshops include technical information, policy issues, marketing. For information, contact CSA, P.O. Box 1300, Colfax, CA 95713, (916) 346-2777.

January 13. New England Low Input/Sustainable Agriculture Conference, in Fairlee, Vermont. Farmers, researchers, and others will explain low-input, sustainable systems. Contact Brian Pillsbury, NH/VT Chapter, Soil and Water Conservation Society, 69 Union Street, Winooski, VT 05404.

January 25-27. Biological Farming for the 90s, sponsored by Trans-National Agronomy, in Grand Rapids, Michigan. Speakers include Dr. Philip Callahan. For information, contact Ronald Ward at 1-800-456-6878.

February 6-10. International Symposium on Natural Resource Management, sponsored by the Indian Society of Agronomy, in New Delhi, India. For information, contact Dr. Anil K. Gupta, Indian Institute of Management, Vastrapur, Ahmedabad, 380 015.

February 15-18. Farm Conference '90, sponsored by the University of California Cooperative Extension, will have a focus on small farms. For information, contact the Small Farm Center, University of California, Davis, CA 95616, (916) 757-8910.

February 15-20. 1990 AAAS Annual Meeting in New Orleans, Louisiana. Meetings include 11 sessions on sustainable agriculture, biological pest control, and related topics. For information, contact the American Association for the Advancement of Science, 1333 H Street, NW, Washington, DC 20005.

March 2-3. Farming for Profit and Stewardship, a Pacific Northwest symposium on sustainable agriculture sponsored by the Extension and Research Station Directors of Oregon, Washington, and Idaho State Universities, with a grant from the USDA LISA Program. For information,contact Daniel McGrath, OSU Extension, 3180 Center Street, NE, Room 160, Salem, OR 97301, (503) 588-5301.

March 6. Learning from Each Other: New Models for Sustainable Agriculture Research and Information, sponsored by the Institute for Alternative Agriculture in Washington, DC. Roland Bunch of World Neighbors in Honduras, Central America, will give the keynote address on partnership successes and potentials. For information, contact the IAA, 9200 Edmonston Road, Suite 117, Greenbelt, MD 20770, (301) 441-8777.

March 16. Research Symposium, sponsored by the University of California Sustainable Agriculture Research and Education Program (SAREP), in Sacramento, California, to present results from research funded by the program in its first three years. Contact SAREP, University of California, Davis, CA 95616, (916) 752-7556.

March 16-21. 55th North American Wildlife and Natural Resources Conference, sponsored by the Wildlife Management Institute, in Denver, Colorado. Contact the WMI, 1101 - 14th Street, NW, Suite 725, Washington, DC 20005, (202) 371-1808.

March 23-24. National Conference on Organic/Sustainable Agriculture Policies, sponsored by the Center for Science in the Public Interest, in Washington, DC. Focus will be 1990 Farm Bill proposals. Contact CSPI, 1501 - 16th Street, NW, Washington, DC 20036, (202) 232-9110.

April 4-6. National Symposium for Stand Establishment in Horticultural Crops, organized by the University of Minnesota, at the Minneapolis-St. Paul Airport Hilton. Contact Cathy Bergum, Minnesota Extension Service, 405 Coffey Hall, University of Minnesota, St. Paul, MN 55108, (612) 625-2722.

April 22. Earth Day 1990. Plans include activities on global to local levels. Contact Earth Day 1990, P.O. Box AA, Stanford University, Palo Alto, CA 94305.

July 29-August 1. Water Futures, the 45th annual meeting of the Soil and Water Conservation Society, in Salt Lake City, Utah. Contact Tim Kautza, SWCS, 7515 NE Ankeny Road, Ankeny, IA 50021.

August 12-15. Conserv 90, a conference on water supply solutions for the 1990s, sponsored by the American Water Resources Association and others, in Phoenix, Arizona. For information, contact Conserv 90, 6375 Riverside Drive, Dublin, OH 43017, (614) 761-1711.

September 26-29. International Symposium on Agroecology and Conservation Issues in Temperate and Tropical Regions, in Padova, Italy. The emphasis will be on the interrelation and transfer of research and application in sustainability and environmental problems between temperate and tropical areas of the world. For information, contact M. G. Paoletti, Department of Biology, Padova University, via Trieste, 75, 35100-Padova, Italy.

Call for papers on indigenous tree management

The Center for Indigenous Knowledge for Agriculture and Rural Development seeks listings for a comprehensive bibliography on the use of indigenous knowledge for private tree management. This includes ecological relationships of trees, crops, and the soil. Send information to Olivia Muchena at CIKARD, Iowa State University, 318 Curtiss, Ames, IA 50011.

Roland Bunch of Honduras will keynote IAA symposium

Roland Bunch, Area Representative for World Neighbors in Honduras, Central America, will give the keynote address at the March 6, 1990, IAA symposium in Washington, DC. The topic of Bunch's talk will be "The Meaning and Benefits of Partnership in Agricultural Research and Information: Past Successes, Future Potentials."

Three panels will address different aspects of partnerships in sustainable agriculture. A morning session called "Learning from Each Other: Three Perspectives" will be moderated by William Liebhardt of the University of California, Davis. Panelists will include Robert Miller of the University of Rhode Island, Charles Francis of the University of Nebraska, and Richard Thompson of the Practical Farmers of Iowa.

The second panel session, moderated by Michael Heller of the Chesapeake Bay Foundation's Clagett Farm in Maryland, will address "Involving Farmers in Agricultural Research." Panelists will be John Gardner of North Dakota State University, Kay Thornley of Davenport, California, and William Lockeretz of Tufts University.

The third panel, moderated by Jerry DeWitt of Iowa State University, will speak on "New Models and New Visions." Panelists include Myron Johnsrud, Administrator of Extension, USDA, and Richard Sauer of the National 4-H Council. Jim Bender of Weeping Water, Nebraska, and Ward Sinclair of Warfordsburg, Pennsylvania, will respond to the panelists.

Participants will be welcomed by Mrs. Jean Wallace Douglas, President of the Institute. Opening remarks will be given by Charles Hess, Assistant Secretary for Science and Education, USDA, and Gordon Watkins of Parthenon, Arkansas.

Use sustainability as overall theme for 1990 Farm Bill, IAA urges Congress

Congress should use the goal of sustainability "as the principal organizing theme in fashioning the 1990 Farm Bill," IAA Executive Director Garth Youngberg told the Research Subcommittee of the House Agriculture Committee on July 19. To make this discussion meaningful, some criteria for what count as methods which achieve more sustainability would need to be developed, Youngberg suggested. "Merely labeling a particular production method as 'sustainable' does not guarantee that it is," he commented.

"Those who favor low-input and other alternative farming systems would welcome the opportunity to have these systems evaluated in relation to a thoughtful set of sustainability criteria," Youngberg said. Taking this approach would imply evaluating commodity programs as well as conservation sections of the farm bill by the criteria of their support for sustainability, an approach radically different from past farm bills.

Rep. George Brown (D-CA) called the hearing to ask whether sustainability is an operable concept for 1990 Farm Bill discussions. "I would argue that U.S. agriculture is not now sustainable, given the billions of dollars we pour into agricultural subsidies, the environmental problems we face with soil erosion and water quality, and the rural distress that continues to linger....We need a new vision and some goals to work towards in the next farm bill," Brown said.

Dennis Keeney of the Leopold Center for Sustainable Agriculture in Ames, Iowa, joined Youngberg in supporting sustainability as a central goal for the 1990 Farm Bill. "A whole-systems approach to research, coupled with direct input in the research agenda by farmers and conservationists, is the only way we can achieve sustainability," he remarked. "All provisions in all sections of the farm bill must meet the criteria of sustainability, else the bill will become riddled with inconsistent provisions working at cross-purposes," commented Raymond Weil of the University of Maryland.

Bezdicek, Sinclair, Heller named to IAA Board

At their meeting on September 9 in North Carolina, the Institute Board of Directors elected three new members. David F. Bezdicek, Professor of Soils at Washington State University, has done research in a wide variety of alternative agriculture techniques. Ward Sinclair, a Pennsylvania organic grower of specialty vegetables and a writer, was formerly an agricultural reporter for the *Washington Post*. Michael Heller is Director of Clagett Farm in Maryland, a 285-acre research and demonstration farm operated by the Chesapeake Bay Foundation to educate farmers and the public on environmentally sound farming methods. The three will begin their terms in March, 1990.

Leaving the IAA Board at the March, 1990, meeting will be Earl Lawrence, Thomas B. Harding, and Jean Wallace Douglas. In recognition of her central role in the life of the Institute, the Board named Mrs. Douglas Honorary President for life. Mrs. Douglas currently serves as President of the Board. In addition to their regular business, the Board toured the low-input research center coordinated by Dr. Larry King of North Carolina State University.

Conference on farmer participation in research for sustainable agriculture

How farmers can participate more effectively in sustainable agriculture research was discussed by farmers, researchers, extension workers, and agricultural administrators at a one-day conference at the University of Arkansas, Fayetteville, October 8, 1989. The conference took place immediately before an international conference on Farming Systems Research and Extension (the ninth in a series), which enabled many people to attend both. Its organizers were the Arkansas/Oklahoma LISA Network, a coalition of about twenty groups concerned with sustainable agriculture research and education. Representatives of two organizations in this coalition respectively introduced and wrapped up the conference: Jim Lukens, of Appropriate Technology Transfer for Rural Areas (ATTRA), and Theresa Maurer, of the Kerr Center for Sustainable Agriculture.

The program offered a variety of formats, including panel discussions, displays, and workshop sessions. It also included three plenary speeches, all of which, as it turned out, were by people associated with this journal. Charles Francis gave the keynote address on the theme "Closing the Information Cycle: Participatory Methods for On-Farm Research." He discussed the importance of on-farm research as a way to expose researchers to a broader set of ideas, to develop information that farmers will consider believable, and to improve the flow of information among all those involved in developing and using it -- farmers, researchers, and extension workers. He contrasted this approach with the traditional information transfer system, in which information flows mainly in one direction, from researchers through extension to farmers.

William Lockeretz's luncheon address was on the question "On-Farm Research: What is it, what is it not?" He noted that some people fail to distinguish research from other similar-looking on-farm activities whose purposes are different, such as demonstrations, or solving a particular problem for a particular farmer, or training farmers to be able to solve problems themselves. Another point he made was that the concept of on-farm research should not be taken to mean that farmers necessarily have a major role in choosing the research question and experimental plan. Although this might be appropriate for some projects, he believed that in general these responsibilities should remain the researchers'.

The closing session featured Neill Schaller's "USDA LISA Update." He described the greatly improved acceptance of low-input sustainable agriculture, for example, as shown by the increasing coverage in the popular and farm press. An especially good example was the very widespread attention given to the recent report on alternative agriculture issued by the National Academy of Sciences. However, he cautioned that in certain circles strong antagonism remains against the idea of substantially reducing the use of agrichemicals.

The program also included two plenary panel discussions. The first described specific on-farm activities in Iowa and Arkansas, presented by either a researcher, an extension worker, or a cooperating farmer. The second dealt with how farmers can influence the land grant system's research agenda to give more attention to sustainable agriculture. In addition, three panels in parallel sessions covered more specific aspects of on-farm research: topics and methods appropriate for on-farm research; funding sources; and how to get farmers and researchers to cooperate.

A somewhat unusual part of the program was three sessions that simulated planning meetings for on-farm research. In each, a farmer, a researcher, and an extension worker or research coordinator talked over the objectives, research questions, and methods of a hypothetical on-farm project. These discussions pointed out the constraints affecting farmers and researchers respectively and considered ways that potential incompatibilities could be resolved.

Because the conference theme has only recently begun to attract so much interest and because the participants represented such a broad range of backgrounds, it was understandable that only rarely did the discussions produce general agreement. Indeed, the diverging opinions exchanged among panelists and between audience and speakers were among the most interesting and lively features of the program. If there was a common thread running through the conference, it was that the agricultural research establishment is showing an unprecedented interest in collaborating with farmers in on-farm research but that problems and barriers remain. Notable among these are the difficulties often encountered in getting proper professional recognition for interdisciplinary research, and some researchers' unwillingness to accept the untraditional experimental designs sometimes needed in on-farm work. The conference organizers, speakers, and audience all recognized that, along with specific research projects, these larger, generic issues must be dealt with as well.

Note: The organizers plan to issue a written report of the conference. For information, write to Jim Lukens, ATTRA, P.O. Box 3657, Fayetteville, AR 72701.

Guide for authors

AJAA will publish original research on biological, physical, or social science aspects of alternative agriculture. We particularly welcome multi-disciplinary studies, but papers from a specific discipline also are invited. However, since AJAA readership is much broader than for a single-discipline journal, highly specialized terminology should be explained or avoided. The significance of a statement, or the reasoning behind a conclusion, may have to be spelled out more than in a more specialized journal. Research papers usually should be no longer than about 20 double-spaced pages.

Nomenclature and technical details

Research papers should use the International (SI, or metric) system throughout. Write out "liters". "Metric ton", although not strictly an accepted SI unit, can be used for data referring to "ordinary life," such as national crop output, as opposed to experimental data. Occasional use of common unit equivalents in parentheses is permitted, mainly for relatively exotic SI units.

The binominal or trinominal designation of a plant or animal species, and the cultivar where relevant, should be given in parentheses the first time the common name of the species is mentioned. Either name may be used thereafter. The same applies to names of chemicals that have both a common name and a chemical name. Do not use brand names except where the chemical is produced under a unique brand name. In those cases the brand name, identified as such, may be given the first time the chemical is mentioned. Nutrient applications should be given in elemental form (N,P,K). Oxide forms can be used in describing commercial fertilizers.

Title page

The title page should give the following information (all flush left): 1) title of the paper; 2) names of authors; 3) affiliation and office address of authors, and 4) acknowledgements, if any. See examples in this issue of AJAA.

Abstract

The abstract should be 200 to 400 words suitable for readers from a broad range of disciplines. It should avoid highly-specialized terminology that might be appropriate for a single discipline journal. Take particular care that the significance of the work is made clear, even to readers from a different field.

Reference list

References should be listed in alphabetical order by author's name, and by year for a particular author (with letters after the year if needed). If a sole author is also the lead author of papers with multiple authors, use the following order: single author (by year); two authors (alphabetically by second author's name); three or more authors (by year). Repeat the author's name for each reference. Use initials only for first and middle names. Give the names of all authors in the reference; never use "et al."

Use full names of journals, institutions, conferences, etc., except for extremely familiar abbreviations like "Dept." Remember that an abbreviation familiar to you may not be familiar to readers outside your field. If in doubt, write it out.

The reference list uses no quotation marks, italics, boldface, or underlining. Only the names of books and periodicals are in initial capitals. Names of papers, book chapters, pamphlets, and bulletins are not capitalized. Page numbers are written out in full (e.g., 1108-1123, not 1108-23). The volume is given if page numbers begin at 1 for each issue.

Citing references

Cite references in the text by last name and year, with chapter or page numbers if the reference is a book or lengthy report. For two authors, give both names. Do not use "et al." unless there are at least three authors.

Footnotes

AJAA does not use bibliographic or substantive footnotes. All bibliographic references should be at the end of the text. Instead of substantive footnotes, include the material in the main text or consider eliminating it.

Manuscript preparation

The entire manuscript, including abstract and references, should be typed on one side of standard-size paper, double spaced, with margins of at least one inch all around. Starting with the title page, label all pages in the upper righthand corner with the lead author's last name and the page number. Do not use hyphens unless the hyphen is part of the word. Do not underline anything except species names.

Follow the section headings style used in this AJAA issue. All headings are flush left, with no underlining or italics.

Tables should fit on one page, be numbered consecutively with Arabic numerals, and be on a separate sheet. Leave extra space to separate columns. Every figure and table should be mentioned at least once in the text.

Submission of manuscripts

Submit four high-quality copies to Editor, American Journal of Alternative Agriculture, Suite 117, 9200 Edmonston Road, Greenbelt, MD 20770. The cover letter should state that the manuscript is an original contribution that has not been published elsewhere in substantially the same form; that it is not currently under consideration elsewhere, and that permission has been obtained for any copyrighted material used.

How you can help support the scientific and educational needs of a sustainable agricultural system

A growing number of Americans have become concerned about the long-term sustainability of our food production system. Farmers and agricultural scientists are among those raising questions about the growing dependence of modern farming on nonrenewable resources, the depletion of our resource base through soil erosion, and heavy reliance on chemical fertilizers and pesticides. Continued heavy reliance on farm chemicals is questioned because they have become an expensive production input. Their widespread use also raises questions about human and animal health, food quality and safety, environmental quality, and the continued demise of the family farm.

Low-input alternative farming methods address these economic and environmental challenges. Alternative production systems point the way toward more profits, more individual choice, and long-term sustainability for our food system. More must be done to develop effective ways to make sure research, education, and information sources are readily available to farmers who want to adopt these techniques.

The Institute for Alternative Agriculture needs your help in meeting this challenge. We are a nonprofit tax-exempt research and education organization set up in 1983 to encourage and facilitate the adoption of low cost, resource conserving, and environmentally sound farming methods. We work directly with government agencies, colleges and universities, producer groups, and other institutions that provide research, education and information services to farmers.

The Institute also provides these services:

- *A resource to lawmakers and others who influence agricultural research, education, and information policy*
- *A voice for alternative agriculture in Washington*
- *A sponsor of research and education outreach programs*
- *A national clearinghouse for information on alternative agriculture*
- *A publisher of reliable scientific information on agricultural sustainability*

If you're interested in helping us, please contact our office at 9200 Edmonston Road, Greenbelt, MD 20770. The phone number is (301) 441-8777.

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